TUNGSTEN MINING AND MILLING IN BOULDER COUNTY, COLO.

By Carl Belser

* * * * * * * * * * * **information circular 7936**

March 3, 1849

UNITED STATES DEPARTMENT OF THE INTERIOR
Fred A. Seaton, Secretary

BUREAU OF MINES
Marling J. Ankeny, Director

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TUNGSTEN MINING AND MILLING IN BOULDER COUNTY, COLO.[1]

by

Carl Belser[2]

INTRODUCTION AND SUMMARY

This information circular is being published by the Bureau of Mines as one of a series in which mining and beneficiation methods and factors pertinent to metal production are described.

In 1955 the Bureau published Information Circular 7721, in which the tungsten ore reserves of Boulder County, was the chief subject. The methods of extracting a marketable product from the raw tungsten ores were also described in some detail, but methods of developing and mining the ores were mentioned briefly.

The mining and milling practices and the tungsten mines operating in Boulder County in December 1956 are described more fully in this circular. For the convenience of the reader this supplement contains certain information, such as the history of the district and the general geology that has been published before.

ACKNOWLEDGMENTS

Appreciation is expressed to the many tungsten-mine operators in Boulder County, who, without exception, cooperated in providing data for this report. Publications of the Federal Geological Survey and the Bureau of Mines were most helpful and are included in the bibliographic references listed on the last page of this report. Permission to publish much information from confidential reports to the Defense Minerals Exploration Administration was obtained from the mine owners and others concerned.

LOCATION AND PHYSICAL FEATURES

The main tungsten-bearing veins in Boulder County, Colo., are within an area 9 1/2 miles long and 4 1/2 miles wide. It extends southwesterly from Arkansas Mountain, 4 miles west of Boulder, Colo., to Sherwood Flats, which is 1 1/2 miles northwest of Nederland, Colo. (figs. 1 and 2). A few small tungsten mines and several potentially important horn-ore deposits lie outside this main district.

1/ Work on manuscript completed February 1959.
2/ Mining engineer, Bureau of Mines, Region III, Denver, Colo.

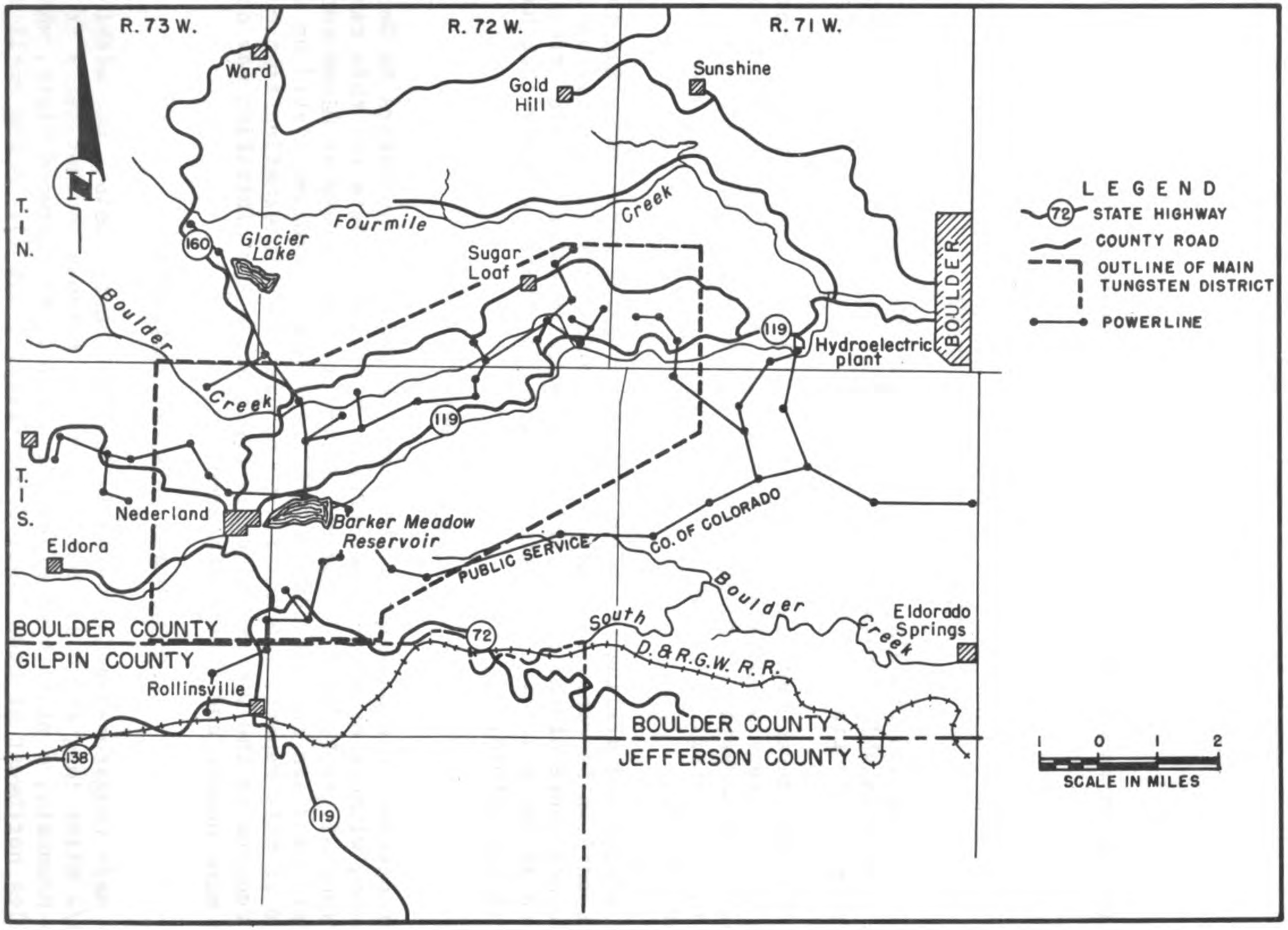

FIGURE 1. - Main Tungsten District of Boulder County, Colo.

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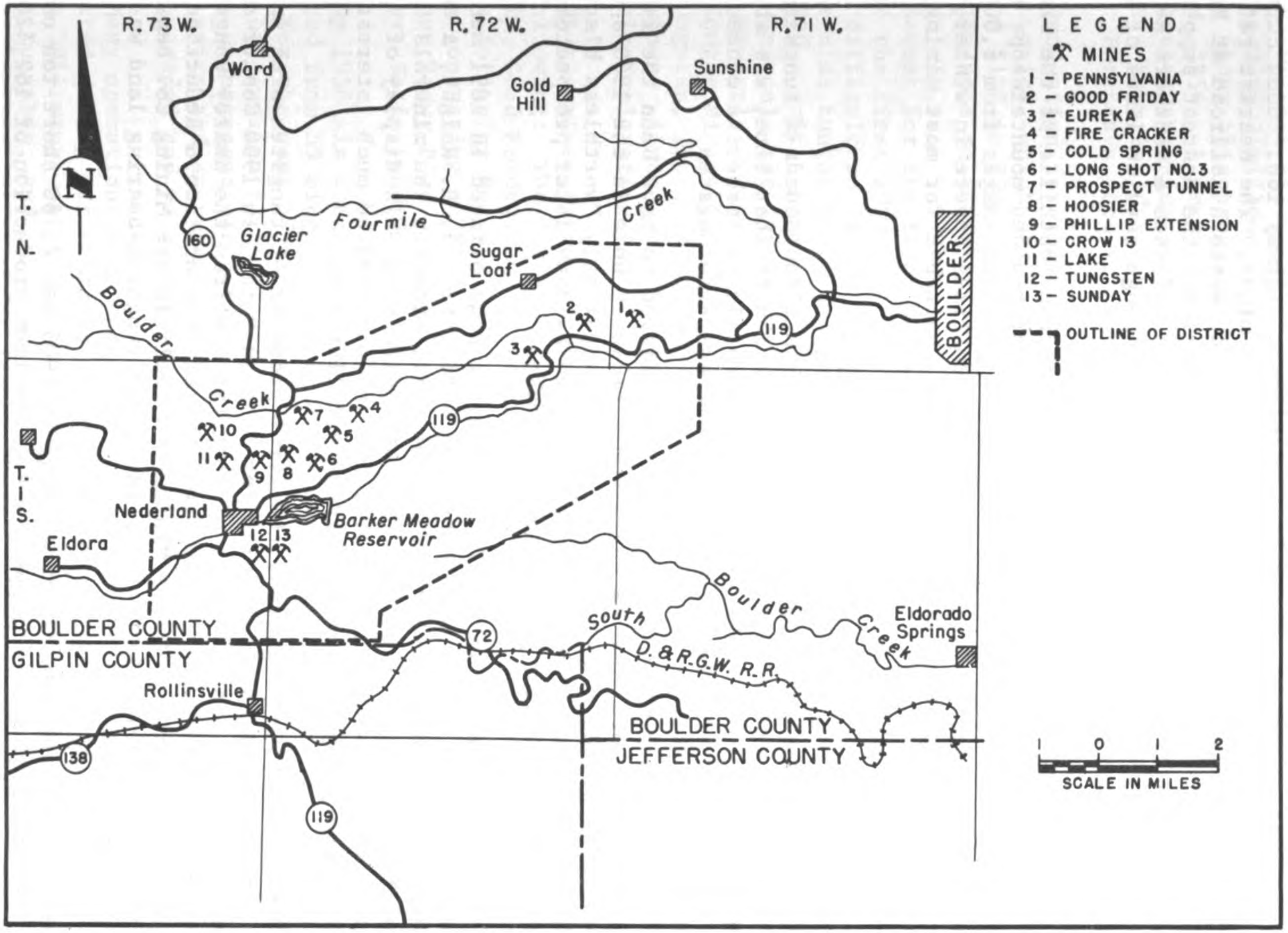

FIGURE 2. - Tungsten Mines Operated in Late 1956, Boulder County, Colo.

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State Highway 119 follows Boulder Canyon from Boulder to Nederland, a distance of 18 miles, where it connects with State Highway 160. Good access roads extend from these highways to the principal mines. The nearest railroad-loading facilities are those of Denver & Rio Grande Western Railroad at Rollinsville, Colo., 4 miles south of Nederland. Boulder, the nearest supply point, is served by Union Pacific Railroad Co. and Colorado & Southern Railway Co. Electric power is supplied to the district through service lines of Public Service Co. of Colorado.

The region is an upland rising westward from the foothills of the Front Range to the steeper mountain slopes. This area of rounded mountaintops and flat ridges separated by narrow valleys and deep canyons ranges from 6,000 to 9,500 feet in altitude; the climate, although sometimes severe in winter, permits year-round mining. Abundant native timber, suitable for most mining uses, grows in the area.

HISTORY AND PRODUCTION

During the period 1900-1955 approximately 30 million pounds of tungsten trioxide, 13.9 percent of the total national production to that time, was shipped from Boulder County. The tungsten was shipped mostly as ferberite concentrate, but some was shipped as tungstic acid and some as ferrotungsten.

Towner, a Boulder County gold miner, is believed to have been the first man to find tungsten ore when he dug a small prospect hole in the 1860's near the present site of the old Conger shaft. The apparently "worthless black iron" that he discarded from this hole was noted by many later prospectors, among them Samuel B. Conger and Nelson Wannamaker.

The Manual of Mineralogy and Petrography by Dana printed in 1891 mentions the Golden Queen mine at Ward as containing scheelite. J. H. Knight, a successful Boulder County miner, recognized in the early nineties the minerals hübnerite and wolframite in mines between Ward and Gold Lake. His display of tungsten ores at the Paris Universal Exposition in 1899 aroused much interest in the Boulder County deposits among foreign metallurgists.

Beddig, in 1899, was probably the first producer of tungsten ores in Boulder County. He mined the Beddick (or Beddig) vein. In 1900 Conger and Wannamaker reportedly mined 40 tons of tungsten ore from the nearby Conger vein. In 1901 Morris Jones founded Great Western Exploration & Reduction Co., which later became part of Primos Mining Co. Wolf Tongue Mining Co. began mining in the area in 1904. Most of the favorable tungsten-bearing land was located by 1905.

Production of tungsten trioxide (WO_3) in 1900 was 2,760 short-ton units valued at about $1.25 a unit (appendix 1). Maximum production of 162,420 units was achieved in 1917; the production was 15,935 units in 1955. From 1900 to 1948 Boulder County produced about 20 percent of the tungsten in the United States but from 1949 to 1955 only 1.8 percent.

The General Services Administration was authorized in May 1951 to buy 1,468,750 short-ton units of tungsten trioxide at $63 a unit; the quota was increased to 3 million short-ton units on August 1, 1952. In Boulder County buying under this program was begun on August 17, 1952, and was completed on June 8, 1956. A second Government program, to buy 1,250,000 short-ton units of tungsten trioxide at $55 a unit, was authorized August 31, 1956. The first purchase from Boulder County under this second program was made September 17, 1956. Purchases were stopped on December 10, 1956, owing to lack of funds.

Production for the most part has been related directly to a fluctuating market price, which has ranged from a low of $1 a short-ton unit in 1900 to a high of $105 in 1916. The drop of production in 1954-55 was due largely to unwillingness to invest on an uncertain market.

Except for the float beds, surface ore deposits were largely depleted during the first 10 years of mining, and underground deposits became increasingly difficult to find. In 1917 Boulder County tungsten miners could no longer mine tungsten ore and keep up the required development work for less than $20 a unit. From 1918 to 1937 the price of tungsten was below $20 a unit, and only the larger companies continued to develop some part of their mines properly. Since then large ore deposits have been found and worked by Wolf Tongue Mining Co. in the Illinois and Cold Spring mines; by Gold, Silver, and Tungsten, Inc., in the Vasco 6 mine; and by lessees in the Mammoth and Quay mines. Since 1951 all major ore discoveries have resulted from Defense Minerals Exploration Administration (DMEA) programs.

Of the mines discussed in this report, DMEA programs were conducted at the following: The Tungsten, Prospect Tunnel, Cold Spring, Eureka, Hoosier-Phillip, Good Friday, and Pennsylvania. DMEA also participated in projects at the following Boulder County tungsten mines not discussed in this report and not operating in December 1956: Vasco Nos. 4 and 5; Vasco Nos. 2, 5, and 8; Range View; Blue Jay; Hallie "A"; Big Six; Gale; Big Cameron; Forest Home; Dorothy, Katie, and Gold Coin; Rambler and Missing Link; Poopout; World.

By 1956 six tungsten mills were being operated (fig. 3). Tungsten was produced from 59 mines in the Boulder County district in 1955. The individual yield for the year of 39 underground mines ranged from 0.9 to 3,654 short-ton units of tungsten trioxide and aggregated 12,280 short-ton units. In addition to the underground mines, 17 sorted mine dumps or float beds yielded 9.7 to 1,097 units and aggregated 2,896 units. At three operations old mill tailings were upgraded and yielded an aggregate of 744 units.

Many operations were small and short lived, a number of them having been conducted during off hours by students or others who normally had other jobs. During 1956 many operations were shut down because the Government had ceased buying tungsten, and in December 1956 only 13 mines were being operated. Their locations are shown in figure 2, and their workings and methods of mining and beneficiating ores are described in this report.

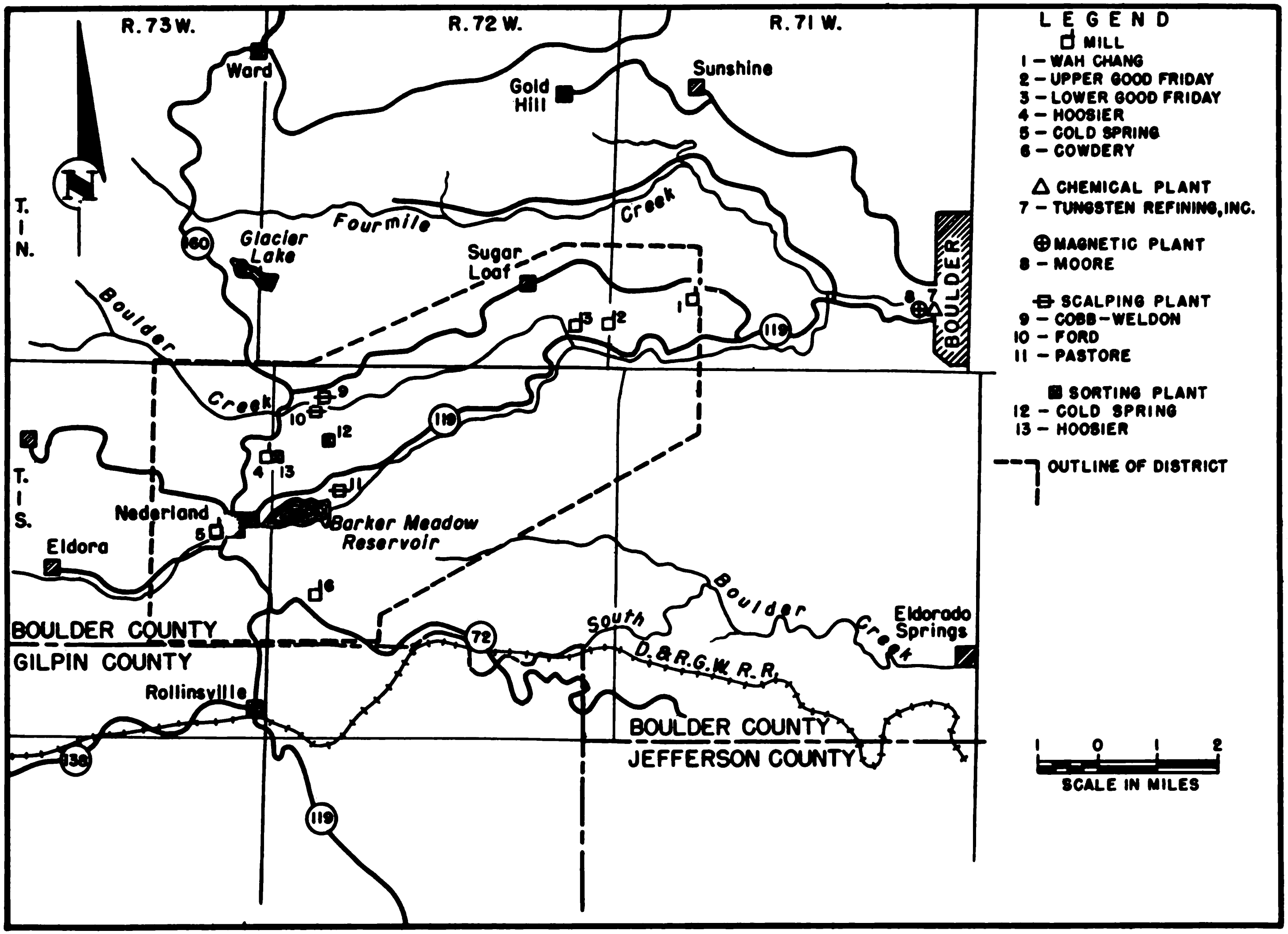

FIGURE 3. - Tungsten Mills and Plants, Boulder County, Colo.

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LABOR AND LIVING CONDITIONS

Adequate skilled labor may be obtained from Nederland and Boulder. Prevailing wages in 1956 were $1.60 and $1.80 an hour. Houses could be rented in Nederland, Tungsten, and other camps in the tungsten district, but most miners lived in Boulder and drove to and from work.

GEOLOGY

Following is a synopsis of the description of the geology in the Boulder County tungsten district presented by Lovering and Tweto (10).[3]

About three-fourths of the tungsten district is underlain by a batholith of Precambrian gneissic quartz monzonite, locally called Boulder Creek granite, which extends from about 1 mile west of Boulder to the Barker Meadow Reservoir.

The remaining one-fourth of the district borders the batholith on the west and is underlain by Precambrian metamorphic rocks, principally the quartz-biotite schist of the Idaho Springs formation that has been intruded by aplite and pegmatite masses related to the batholith. These Precambrian rocks are cut by dikes of Late Cretaceous or Early Tertiary age, consisting of predominantly hornblende-monzonite porphyry and hornblende-diorite porphyry in the western half of the district, and biotite porphyry and biotite breccia in the eastern half. The first of two major fracture systems trends northwestward and contains most of the productive tungsten veins. Faults trending northwestward, locally called breccia reefs, cross the district and can be traced on the surface for many miles.

The tungsten-bearing veins generally are narrow and irregular and have small ore shoots ranging from a few inches to 3 feet in thickness. In a few places, veins as much as 16 feet wide have been mined. The ore is mostly ferberite disseminated through quartz, which constitutes the principal vein material. Scheelite is found in the district, but no commercial scheelite deposits are known. Hubnerite has been found as a minor ore constituent in the Quay mine.

Ore has been mined over a vertical range of 2,500 feet in the district, although most of the individual ore shoots have been extended less than 100 feet below the surface. Many ore shoots doubtless exist that do not crop out.

Description of Deposits

The production from most of the 59 properties operated in 1955 was very small. In 1956 the drop in the price of tungsten trioxide and the discontinuance of Government buying caused many smaller producers to close their mines. The locations of properties that were active the latter part of 1956 are shown on figure 2. Three of the better known deposits are described below.

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[3] Underlined numbers in parentheses refer to items in the bibliography at the end of this report.

Eureka

The Eureka vein has been productive over a length of about 3,800 feet and a vertical range of about 900 feet (fig. 4). The vein strikes N. 55° to 75° E. and dips 75° to 85° NW. between walls of Boulder Creek granite. The vein structure varies from a small, tight fracture to a sheeted zone several feet wide and contains three main ore shoots, which range from 1 inch to 4 feet in width. One to three feet of the wall rock on both sides of the vein usually is argillized.

Other veins probably intersect the Eureka vein, but no work has been done to prove that other strong veins exist. As a whole, the ground stands well except in the wider argillized areas where it tends to slough. Data furnished by the late J. G. Clark give the production through 1955 at 26,479 units of tungsten trioxide. The mine is opened by about 4,600 feet of drifts and crosscuts.

Good Friday

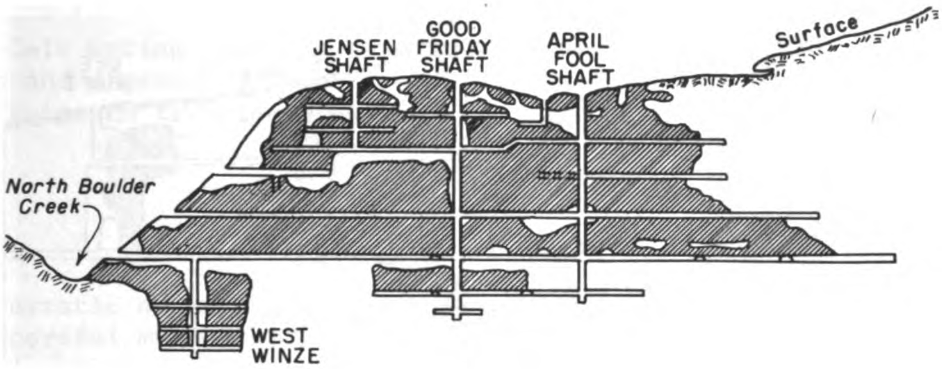
The Good Friday vein has been productive over a length of 1,600 feet and a vertical range of about 550 feet (fig. 4). It strikes N. 60° E. and dips 60° to 80° NW. The walls are moderately chloritized and argillized; in general, the vein structure varies from a tight fracture to a sheeted zone 2 to 4 feet wide. The Good Friday vein intersects two other veins near the middle of the mined-out area--the Pleasant Dream vein, which strikes N. 75° E., and the Spur vein, which strikes N. 45° E. The country rock is Boulder Creek granite, and usually the ground stands well. Data furnished by Ira Tanner and George Jump show that the total production through 1955 was 94,464 units from the April Fool shaft and 41,332 units from the Good Friday shaft. The total production from the Good Friday ore shoot through 1956 was about 139,000 units. The mine is opened by three shafts and about 6,500 feet of drifts.

Cold Spring

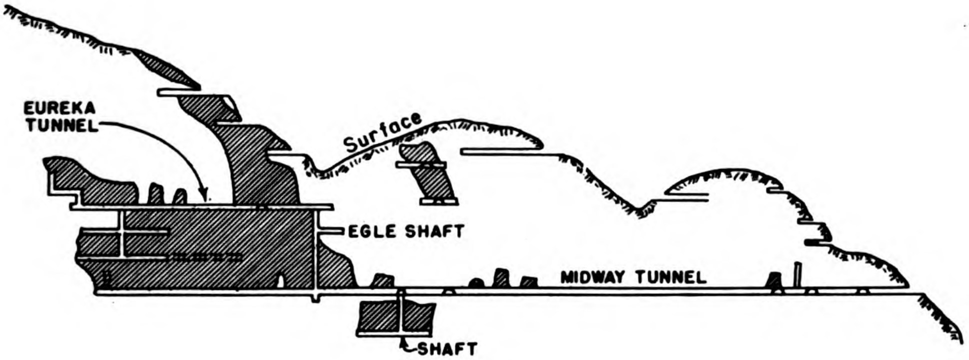
The Cold Spring vein has an average strike of N. 75° E. and dips steeply northward between walls of Boulder Creek granite (fig. 5). The vein has been opened to a depth of 430 feet and a length of 2,600 feet. The vein walls, generally, are hard to a depth of 12 to 20 inches; beyond this depth, the walls are argillized and soft to a depth from three to five times the thickness of the vein. The ground sloughs badly.

The vein filling is of three types: Barren, unmineralized unsilicified gouge; barren fine-grained horn quartz; and intergrown horn quartz and ferberite. The last type is characterized by moderately fine-grained masses, pods, and streaks of ferberite ($FeWO_4$) cementing a breccia, composed of horn quartz and wall-rock fragments.

Many branch veins diverge from the Cold Spring vein at acute angles, and most of the ore in the Cold Spring vein is near the vein junctions.

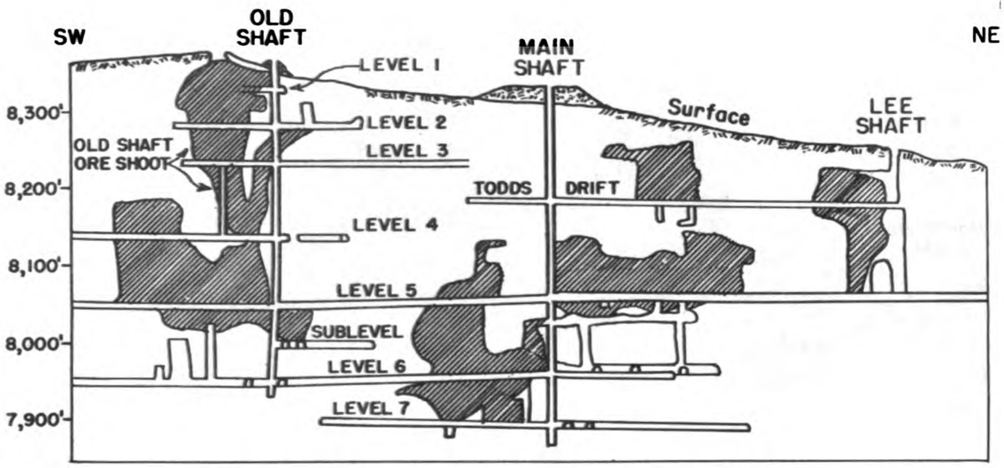


LONGITUDINAL PROJECTION ALONG GOOD FRIDAY VEIN



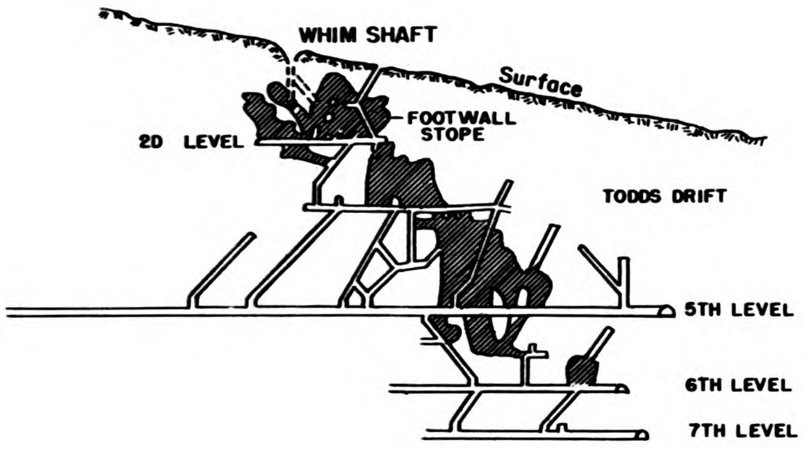
LONGITUDINAL PROJECTION ALONG EUREKA VEIN

FIGURE 4. - Longitudinal Projections Along Good Friday and Eureka Veins.



LONGITUDINAL PROJECTION OF THE COLD SPRING MINE

FROM GEOL. SURVEY BULL. 922-F



LONGITUDINAL PROJECTION OF SHARKEY-RL VEINS

FIGURE 5. - Longitudinal Projections Along Cold Spring and Sharkey Veins.

Six ore shoots were found in the Cold Spring vein; four of them were large. The junction of the Sharkey-R.L. vein is in the footwall of the Cold Spring vein, and a large ore shoot was found near it.

The Cold Spring mine was developed through three shafts with 12,000 feet of drifts and crosscuts. Its production, through 1955, was 136,164 short-ton units of tungsten trioxide.

MINES AND MINING METHODS

General

The erratic occurrence of the ore and the terms under which it was sold required careful mining by selective methods. Little ore was ever developed ahead; only minimum plant and equipment were warranted, and skillful management was needed to conduct a profitable operation.

Prices for some of the major supplies used in the Boulder County tungsten mines in 1956 were approximately:

Item:		Price
No. 6 blasting caps	hundred	$2.80
Fuse, 3,000-ft. spool	foot	.013 (or 39.79)
Rail, 16-lb	ton	140.00
Explosives, Gelex No. 2	cwt.	24.00
Pipe, black iron, 1-in. i. d	foot	.27
Pipe, black iron, 2-in. i. d	do.	.45
Timber, 4- to 6-in., native round	do.	.045
Timber, 8- to 10-in. native round, 8 ft. long	each	2.00

Ores and concentrates were sold by most producers at prices based on a "sliding-scale" schedule (appendix 2). A 1-percent product was worth $17.50 per ton for the contained short-ton unit, whereas a 60-percent product was worth $3,120.00 per ton or $52.00 per contained short-ton unit.

Therefore, it was usually beneficial to the miner to market the best grade product that he could prepare. For example: A 1-inch-thick streak of high-grade tungsten ore that was frozen to a wall of the vein and broken in a shrinkage stope, together with several feet of waste, might result in a 1-percent tungsten trioxide product. A 100-ton ore shipment of this type ore would contain 100 short-ton units and net the producer $1,750 less $200 for haulage, or $1,550. If the same streak were mined in a filled stope, the waste carefully broken, the ore then stripped off the wall, and caught on a canvas, a 40-percent product might result. A 2 1/2-ton shipment of that quality would net the producer $3,368 less $6.00 for haulage or $3,362.

Where the ore occurred as streaks throughout the vein, the filled-stope mining method usually was employed. The stope fill was leveled and covered with a canvas or carpeting, upon which a plank floor was laid. Steel plates were used sometimes to cover the stope fill. The ore and waste were blasted together, and the broken rock was carefully sorted. The pieces of ore and the fines were thrown into the chutes; the discarded waste was kept in the stope for fill. Usually, the ore was sorted again after it reached the surface.

Different ore shoots require different methods for efficient mining, and the more successful miners were those whose practices yielded the highest grade of product feasible.

The mines being worked in 1955 varied in extent from mere surface cuts to one having about 12,000 feet of drifts and crosscuts. The type of hoisting equipment used suited the operation and consisted of hand windlasses gasoline-engine-powered or electric-motor-driven hoists.

Hand mucking was the usual procedure; but in four mines, some mucking was done with machines. Mine cars were trammed by hand, mules, and electrically driven motors. In general, the mining equipment was small, and much of it was makeshift.

All underground mines operated in 1956 had inclined shafts. The Cold Spring shaft had been sunk in country rock; the others had been sunk in veins. When sinking, a high and a low end were maintained at the bottom. Water that collected in the low end was removed by bailing or pumping. Mucking in shafts and winzes was done by hand, and timbering consisted of stulls and wallplates, except in weak ground, where cribbing was used. Speed of sinking was not an important factor; shaft rounds were drilled with 4-foot holes, and the average rate of shaft sinking was 1 1/2 to 2 feet a shift.

A few mine dumps were worked on a small scale by screening followed by hand jigging, but production from dumps was obtained mostly by passing the rock through a trommel and sorting the oversize. The selected ore and the fines were then hauled by trucks to a scalping plant, where an upgraded product was made cheaply by using bull jigs or sluices. The resulting rough concentrate was then jigged again or tabled.

Clyde Mine

The Clyde mine has been operated intermittently since 1907. It was developed to a depth of 500 feet by a shaft, two winzes, an adit that gives access to the third level, and 4,300 feet of drifts and crosscuts. The principal veins in the mine are called the Clyde and the Footwall.

On the third level these veins, about 50 feet apart, strike N. 70° E. and dip 75° NW. through fine-grained granite and aplite. The intervening rock is silicified and sericitized.

Total production from the mine was estimated at 28,000 short-ton units of tungsten trioxide.

Equipment included:

1 compressor, 300 c.f.m., D-1300.
1 hoist, 15-hp., electric, Vulcan.
1 pump, 25-hp., Ingersoll-Rand.
6 mine cars, 18-cu. ft., end-dump.
1 shaft bucket, 8-cu. ft., button-dump.

Water was kept below the fifth level, which was 170 feet above the seventh or bottom level.

In 1956 the fill that was found above the fourth level of an 8-foot-wide underhand stope was of good-ore grade. It was hoisted to the top of the stope, dumped through an old winze to the fifth level, trammed to the shaft, hoisted to the third level, and trammed to the surface. The ore was then hauled to the Hoosier mill, where more than 20 pounds of tungsten trioxide a ton of ore treated was recovered.

After the stope had been emptied, a shoot of good-grade ferberite ore 8 feet wide was exposed in the bottom. It is planned to drive a new drift from the third-level adit to reach this ore.

Cold Spring Mine

The Cold Spring mine (fig. 5) was developed by three shafts with seven levels having an aggregate of about 12,000 feet of drifts and crosscuts. From 1950 to 1956, the mine workings were extended about 2,000 feet by drifting, crosscutting, and raising. Diamond drilling was also done. Stopes were opened on the Sharkey-R.L. veins and on an unnamed vein found near the shaft in hanging wall of the Cold Spring vein.

Equipment included:

2 compressors, 15- by 9- by 12-inch, Ingersoll-Rand, type 10.
1 compressor motor, 440-v., 75 hp.
1 compressor motor, 440-v., 50 hp.
1 electric hoist, 22-hp., Dillon-Box.
1 electric hoist, 22-hp., Denver Engineering Works.
1 centrifugal pump, 150-g.p.m., Fairbanks-Morse.
1 Little Trammer, Mancha.
2 mucking machines, Eimco 12-B.
2 mine tracks, 18-inch-gage; 8- , 12- , and 16-pound rails.
1 shaft skip, 1-ton-capacity, in new shaft.
1 sorting plant at new shaft.

Fifty to one hundred thousand gallons of water was pumped from the mine each day. Compressed air was delivered down the shaft through a 3-inch pipe and to the working places through 2-inch pipe. Thirteen men, including one superintendent, two hoistmen, one mechanic, one truck driver, and eight miners, were employed on one shift when the mine was visited in December 1956.

Prospect raises were driven on the vein at 45° to its dip. Some raises were driven as high as 200 feet without timbering. Their cost was relatively low, but that advantage sometimes was offset because the unsupported ground tended to slough.

The shrinkage-stope method of mining was used. Most stopes were about 4 feet wide, but in places the Sharkey-R.L. stopes were as much as 13 feet wide.

A typical 4- by 12-foot raise round consisted of eighteen 5-foot holes, with a burn cut. The round was drilled by two men using an Ingersoll-Rand No. 38 stoper, and one round was drilled each shift. Each drill hole was loaded with six sticks of 1-inch 45-percent Gelemite and detonated with No. 6 blasting caps on 8-foot fuses. A hot-wire igniter was used.

The broken rock dropped to the level where it was loaded into cars, either by hand or with a mucking machine, and then trammed to the shaft. Labor was performed by contractors, who were paid a rate of $10 a foot of raising.

Two labor-saving devices were made locally. The steelholder was made from a 6- by 12-inch, steel plate, 3/8-inch thick; the four holes drilled along the centerline of the plate were large enough to accommodate drill steel but small enough to prevent the bits from slipping through them; slots, just large enough to permit the drill steel to slide sideways, were cut from the holes to the edge of the plate; a loop was welded at right angles to the opposite edge of the plate; and another loop was hung over a pin (usually a piece of old drill steel) driven into the side of the raise. The adjustable sprag was made as follows: A piece of 2-inch pipe, about 3 feet long, was pointed on one end; two holes, 3/4 inch in diameter and about 8 inches apart, were drilled through the pipe near its open end, and 5/8-inch nuts were welded over the holes; threaded, 5/8-inch rods, bent at right angles, were screwed into the nuts; a 5/8-inch handle was welded to the opposite side of the pipe; a piece of 1 1/2-inch pipe was also pointed on one end; the open end was slipped into the 2-inch pipe; the two pipes were adjusted to the length desired, and tightened in place by means of the two rods. This device was also used to hold a snatch block when slushing.

Drift Rounds

Drifts, 5 by 7 feet in cross section, were advanced with an 18-hole, 6-foot burn-cut round. The holes were drilled with a Copco airleg-type rock drill and loaded with six sticks of 1-inch, 45-percent Gelamite explosive. The charge was detonated with No. 6 blasting caps on 8-foot fuses, using a hot-wire spitter. Drilling time was 2 1/2 hours and mucking time about 3 1/2 hours. A heading crew consisted of two men. Rock broken in a drift round filled fourteen to twenty 16-cu. ft. mine cars and was usually loaded by hand shoveling, but sometimes a slusher or Eimco loader was used. The loaded material was trammed to the shaft and hoisted.

The Cold Spring mine was the district's leading source of tungsten from 1951 to 1956.

Eureka Mine

The Eureka mine was owned by two partners, one a working partner who superintended the mine operations and worked as a miner when not engaged in other duties. The partnership employed one man and four sets of lessees.

The mine was operated through an adit through which the waste and ore were trammed (fig. 4). The adit was steep and crooked, and a mule was used to pull a train of three 1-ton-capacity cars over 12-pound, 18-inch-gage track from the working places on the adit level.

A compressor-changeroom building was on the road below the adit dump. It contained a Joy No. 214, 187-c.f.m. compressor with a 440-volt, 40-hp. electric motor, and a Joy L. W. 81, 287-c.f.m. compressor with a 440-volt, 50-hp. electric motor. Compressed air was delivered to the working places through a 2-inch pipe. Several wooden ore bins with sorting floors were on the side of the dump that faces the road.

The total production of the Eureka mine for 1956 was 3,201 short-ton units of tungsten trioxide.

Main Heading

The adit that was known as the Midway tunnel was the main heading. The present operators extended it 350 feet in 1953; its total length in January 1957 was about 1,650 feet. It is 5 by 8 feet in cross section and follows a vein comprised mainly of quartz and gouge between walls of Boulder Creek granite. When the last 350 feet was driven, an inverted V-cut was used, and twenty 4-foot holes were drilled for each round. Drilling was done with a Thor No. 77 rock drill that was mounted on either a bar or a column. Regular tungsten carbide insert crossbits were used. Each hole was loaded with four sticks of 1 1/8-inch, 45-percent Gelex explosive or 25 pounds of explosive per round. The charge was detonated by No. 6 blasting caps attached to 5-foot fuses. A lead spitter was used to ignite the fuses.

Two men drilled one day and hand-mucked and trammed the next. A mule was used to haul the mine cars; the round-trip distance between the surface and the face was about 3,500 feet.

Sinking

An 82-foot winze (East winze) and a 10-foot sump were sunk on the vein by two lessees. The winze inclined 80° to the north and was sunk from the adit level (Midway tunnel) at a point 150 feet east of the old Egle shaft. It was 5 by 9 feet in cross section, had two compartments, and was timbered with 3- by 8-inch red spruce cribbing. Skids consisted of 2- by 6-inch planks on which 2- by 4-inch strips were nailed. An old Gardner-Denver tugger-type hoist, powered by compressed air, and a 700-pound-capacity bucket were used for hoisting.

In sinking the winze, a Thor handheld sinker drill was used. Twenty 3-foot holes were drilled in the high end of the bottom and loaded with 1-inch 45-percent Gelex explosive, which was detonated with regular-delay electric caps.

The ore was on the footwall and was stripped after every third round. The drilling time per round was about 2 hours.

The lessees timbered, drilled, blasted, mucked, hoisted, trammed 1,000 feet, and sorted ore. The work was done at night, five shifts a week, and about half of the lessees' time was spent in sorting ore. Sinking was begun January 15, 1956, and was stopped July 15, 1956. The owners furnished compressed air, explosives, timber and equipment; the lessees furnished all labor and paid a royalty of 25 percent.

Another winze (Far winze) was started about 200 feet west of the Egle shaft. It was being sunk in 1956 on ore by lessees. Sinking methods were the same as those employed in the East winze.

Winze Drifts

The lessees drove a drift 60 feet west and 40 feet east from the bottom of the 82-foot winze. A Thor airleg-type rock drill was used to drill a 14-hole, 4-foot, V-cut round. Tungsten carbide insert crossbits of both knock-off and threaded types were used. Drilling time was about 2 hours.

The ore was first sorted underground and again in the ore bin, and about 4 tons of waste and 7 tons of ore were broken each round. The lessees furnished everything but compressed air and equipment and paid a 25-percent royalty. From January 15, 1956, when the shaft was started, to December 31, 1956, the lessees produced 1,720 units of tungsten trioxide, worth about $43,000 at the mill. Water was pumped from the winze for 10 minutes every other day with a 100 g.p.m. electric pump.

Footwall Drift on Adit (Midway Tunnel) Level

A drift 5 feet wide and 10 feet high was driven 275 feet along an offshoot that entered the hanging wall from the Eureka vein. An inverted V-cut round of twenty 5-foot holes was drilled with a Thor No. 20 stoper. A Gardner-Denver S-55 drill was used to drill the lifters. The last 200 feet of this drift was driven along ore. The ore was left on the hanging wall while the drift was being driven and was removed later. Drilling time was about 6 hours to the round. Five-foot fuses, No. 6 caps, and a lead spitter were used in blasting. The average round filled sixteen or seventeen 1-ton-capacity mine cars, which were loaded and trammed 800 feet in one shift by the working partner and a helper.

Stoping

Cut-and-fill stopes were opened near the end of the adit (Midway tunnel) level. The stopes were started, and the backs were advanced by drilling 4-foot rounds. Small drill bits were used, and the holes were loaded lightly with 1-inch 45-percent Gelex explosive. A Thermalite ignition cord was used to ignite the 8-foot fuses that were attached to No. 6 blasting caps.

As the stopes advanced, they were filled with waste rock broken with the vein and held by stulls and lagging placed above the level. Access to the stopes was provided at 25-foot intervals along the level through cribbed raises or mill holes, which also served as ore chutes.

The fill was spread evenly in the stope and covered with carpeting, over which a plank floor was laid. The rock broken from the back was carefully sorted on the plank floor. The coarse ore and the fines were thrown down the mill holes; the waste was piled to one side. When the next layer of fill was needed, the planks were taken up, and the fines that were caught on the carpeting were collected. The waste piles were spread over the old fill, and the carpeting and plank flooring were relaid.

Fire Cracker and Crow No. 13 Prospects

Fire Cracker

In 1955 a small prospect shaft was sunk on the Fire Cracker vein to a depth of 35 feet by one man (Ray Flarty). His equipment consisted of a single jack, hand steel, a small wooden headframe, an 800-pound-capacity hoisting bucket, and an old truck, which was used to supply power for a whip. All timber used in the shaft was cut from the claim. The 3 1/3- by 7-foot shaft was cribbed for the first 12 feet and was timbered with stulls and wallplates the rest of the way.

About six buckets of water a day was bailed from the shaft, in which a high end and a low end were maintained in the bottom.

The shaft was sunk by drilling eight 3-foot holes in the high end, and the holes were blasted with 2 1/2 sticks of 7/8-inch, Dupont, 40-percent, gelatin explosive. Three hours was required to clear the shaft of broken rock after blasting and 5 hours to drill the next round. After each bucket was filled, Flarty climbed the ladder and hoisted the bucket with the truck. Thirty-five feet below the surface the shaft broke into old workings. Flarty says that it took him about a month to sink the shaft. The Fire Cracker vein is about 2 feet wide; no ore was exposed in the shaft. The country rock is granite gneiss, and one wall was broken in sinking.

Crow No. 13

In 1956 Flarty sank the first 35 feet of a shaft on the Crow No. 13 claim, using the equipment he had had at the Fire Cracker shaft. He could only work at odd times, as he was employed regularly at another property. When his shaft was 35 feet deep, he obtained the help of a partner who furnished a small, gasoline-engine-driven hoist and a compressor. The shaft was then sunk an additional 10 feet, and a drift was driven 100 feet along the vein.

The vein is about 2 feet wide in granite gneiss and contains a narrow streak of ferberite. The drift is 5 by 7 feet in cross section and was driven by drilling 4-foot V-cut rounds of 11 or 12 holes. An Ingersoll-Rand No. 49 stoper and a Chicago Pneumatic handheld rock drill were used for drilling. The holes were loaded with 1 1/8-inch 45-percent Gelex explosive, which was detonated with No. 6 blasting caps.

About 1 1/2 hours was spent in drilling and about 1 hour in bailing water from the shaft.

Good Friday Mine

The Good Friday mine (fig. 4) is an old mine in which the Good Friday vein has been developed over a length of 1,600 feet and to a depth of 600 feet. The mine workings consist of three adits, three shafts, a winze, and about 6,000 feet of drifts and crosscuts. Most of the vein above the lowest adit was worked out before World War II. The production through 1956 was about 139,000 units of tungsten trioxide. In 1956 ore was produced chiefly from below the lowest adit.

Equipment at the mine included:

1 mine hoist, Mine & Smelter Supply Co., driven by a Dodge 1939-model automobile motor.
1 compressor, 310-c.f.m., Joy Type 75-B, driven by a 440-volt 80-hp. motor.
1 compressor, 210-c.f.m., Jaeger Model A, driven by a 40-hp. electric motor.
10 rock drills.
1 hoisting bucket, 1,600-pound capacity, button-dump.
8 mine cars, 16-cu. ft.-capacity.
1 pump, 10-hp., Worthington, electric.
2 pumps, 5-hp., Worthington, electric.
2 hoists, 11-hp.

A gravity-type concentration plant having a capacity of 20 tons per 16-hour day is near the lowest adit, and a new gravity-type concentration plant having a capacity of 30 tons per 16-hour day was built near the collar of the April Fool shaft. The upper parts of the Good Friday and Jensen shafts had not been repaired.

Ore or waste was transported in 16-cubic-foot mine cars, dumped into steel hoppers at the shaft stations, and loaded into hoisting buckets. Ore from the West winze was trammed through the lowest adit to the old mill, and ore hoisted through the April Fool shaft was dumped from the hoisting bucket directly into the new mill. Twenty-five men were employed on two shifts. Eight men worked in the mills, 15 in the mine, and 2 were hoistmen.

Sinking

The last 100 feet of the West winze was sunk by lessees. The company furnished compressed air, power, and equipment, and milled the ore. The 4- by 8-foot, two-compartment winze was sunk with a high and low end kept at the bottom. The wall rock is Boulder Creek granite, and timbering consisted of stulls and wallplates. Eleven to thirteen 4-foot holes, pointed to provide a center cut, were drilled on the high end of the bottom of the winze with a Thor sinker-type drill. Drilling required 2 1/2 hours. Each hole was loaded with four sticks of 1 1/8-inch Ajax 45-percent explosive. The holes were blasted with regular-delay electric detonators. Returns from ore shipments enabled the lessees to "beat wages" in sinking the last 100 feet.

Drifting

Drifts were driven 100 feet east and 50 feet west from the West winze at its 100-foot level. A Thor airleg-type rock drill was used, and usually a 4- by 7-foot burn-cut round, drilled 5 feet deep, was broken with 16 holes. Each hole was loaded with six sticks of 1 1/8-inch, 45-percent Ajax explosive and was detonated with a No. 6 blasting cap on a 5-foot fuse.

A 4- by 7-foot drift was driven on the bottom level of the April Fool shaft. A burn-cut round of twenty 5-foot holes was drilled. Holes were loaded with 1-inch 45-percent Ajax explosive, which was detonated with No. 6 blasting caps on 6-foot fuses. Thermalite ignition cord was used to ignite the fuses. Drilling time was 4 hours, and the rock broken per round filled twenty-five 16-cubic-foot-capacity mine cars.

Stoping

Ore was mined by shrinkage-stope methods. The ore was screened, and the coarse was washed and hand-sorted at the head of each mill. Crude mill heads were estimated by George Jump, former owner of the Good Friday mine, to have run from 2 to 4 percent tungsten trioxide. In 1956 about 5,500 units of tungsten trioxide was sold in concentrates that contained about 59 units per ton.

In 1954, lessees extracted part of an ore pillar that had been left near the bottom of the Jensen shaft. The lessees avoided rehabilitating the shaft by using 500 feet of flexible 1-inch pipe for an air line and a truck winch to raise or lower men and supplies. The ore was dropped to the lowest adit level and trammed to the surface.

Hoosier-Phillip Extension Mine

The Hoosier-Phillip Extension mine was discovered about 1900 and developed by two shafts and approximately 5,600 feet of drifts and crosscuts. Seven men were employed at the mine; two worked on surface, and five worked underground.

Equipment at the 300-foot Hoosier shaft included:

1 hoist, 20-hp., electrically driven Hendrie & Bolthoff.
1 compressor, 300-c.f.m., 440-v., 50-hp. motor-driven, Ingersoll-Rand, Imperial type 10.
1 pump, 20-hp., electric, Fairbanks-Morse.
1 hoisting bucket, 1-ton-capacity, button-dump.
Mine cars, 18-cu. ft., end-dump type.

Equipment at the 200-foot Phillip Extension shaft included:

1 hoist.
1 compressor, 384-c.f.m., 75-hp. electric-motor-driven, Chicago-Pneumatic.
1 pump, 30-hp. electric, Fairbanks-Morse.
1 hoisting bucket, 1,600-pound-capacity, button-dump.

A gravity-type concentrating mill having a capacity of 25 tons of ore per day was near the Phillip Extension shaft.

The Hoosier, Phillip, Hummer, and No. 10 veins have been exploited in the Hoosier-Phillip Extension mine. The Phillip vein strikes east, and the Hoosier, Hummer, and No. 10 veins strike N. 70° E. The walls of the Hoosier and No. 10 veins are aplite; the walls of the Phillip vein are schist and pegmatite; and the walls of the Hummer vein are aplite and pegmatite.

The total production from the Hoosier-Phillip Extension mine through 1956 was estimated to be 29,700 units of tungsten trioxide.

Crosscutting

In a 4- by 7-foot crosscut in aplite, two men were able to drill an 18-hole 5-foot burn-cut round in 1 1/2 hours, with a Copco airleg-type rock drill, using drill steel fitted with insert chisel bits. Each hole except the cut holes was loaded with five sticks of 1 1/8-inch, Gelex No. 3, 40-percent explosive, which were detonated with a No. 6 blasting cap. A lead spitter was used to ignite the 6-foot fuses.

Two men loaded the broken rock into 18-cubic-foot-capacity mine cars in 4 hours, with the aid of a scraper loader and ramp.

The loaded cars were trammed to the shaft station, and the rock was dumped through a hopper into the hoisting bucket.

Raising

A two-compartment raise, 4 by 7 feet in cross section, was driven on the Hummer vein. The burn-cut raise round, consisting of eighteen 5-foot holes, was drilled by two men in 1 1/2 hours. A Sullivan stoper and an Ingersoll-Rand stoper were used in drilling. Loading and blasting practices were the same as those used in driving the crosscut.

Rock-Loading Device

The operators had built a practical device for loading broken rock. It consisted of a 1/4-inch-thick sheet-metal slide 28 inches wide mounted on a frame made of 3-inch angle iron. The frame was fastened to a mine-car truck, which was provided with clamps to hold it firmly to the track. The front part of the slide was bent downward; and a steel-plate lip was hinged to it. The rear part of the slide was horizontal and provided with an opening beneath which a mine car could be placed. The slusher hoist was mounted above the slide on the angle-iron frame. A pulley at the rear of the slide and a snatchblock hung in the breast of the drift accommodated the pull rope and the tail rope of the scraper, respectively. With this device, the broken rock was pulled up the slide to the opening at its rear, through which it fell into the mine car.

Lake Mine

A small lake just west of the Nederland-Lakewood State Highway 160 was unwatered and a bulldozer used to dig peat from its bed. In May 1956 the bulldozing uncovered a north-striking, steeply dipping vein, which was 12 to 18 inches wide on the surface and was said to be 6 inches wide in the bottom of the shaft. Thirty-six tons of 1-percent tungsten ore, reported to have been worth $3,000, was shipped to the Hoosier mill.

A shaft was started by two lessees in June 1956 and sunk 25 feet before work was discontinued for the winter. The shaft was cribbed for the first 18 feet. Water entered the bottom of the shaft at the rate of 150 gallons a minute.

Equipment and improvements included:

1 hoisthouse in good condition.
1 headframe.
1 hoisting bucket, 10-cu. ft. capacity.
1 generator, diesel-electric, 18-kw.
1 hoist, 15-hp., Dillon-Box.
1 pump, 7 1/2-hp. electric, Fairbanks-Morse.
1 compressor, 125-c.f.m., Chicago Pneumatic.
1 engine, gasoline-driven, Hercules.

Long Shot No. 3 Mine

The Long Shot No. 3 ore shoot was discovered in a bulldozer cut on June 26, 1956. About 1 month was spent in removing ore from the bulldozer cut. Then six miners, working as partners, sank a shaft 100 feet deep, cut a station, and drove a drift along the Long Shot vein, 20 feet west and 112 feet east of the shaft. The ore above these drifts was stoped.

The vein strikes N. 75° E. and dips 70° NW. through Boulder Creek granite and ranges from 12 to 18 inches in width. The broken material was considered ore grade when the panned fines yielded a ferberite concentrate. A 30-inch-wide stope was mined, and no sorting was done underground.

About 400 tons of ore was shipped to the Hoosier mill; and 11 1/2 tons of concentrate, containing 57 percent tungsten trioxide, was said to have been recovered. An additional 300 tons of ore was stockpiled at the mine. It was estimated that this would yield 7 tons of 57-percent concentrate, which would make the total production of the Long Shot No. 3 mine, to date, an estimated 1,055 short-ton units of tungsten trioxide worth about $54,000.

Equipment included:

1 bulldozer, International Model TD-14.
1 hoist, geared to Ford V-8 engine.
1 compressors, 180-c.f.m., gasoline-engine driven, LeRoy.
2 hoisting buckets, 10-cu. ft.-capacity.
1 water bailer, 75-gal.-capacity.
1 headframe, constructed of 4-inch pipe.
2 rock drills, airleg-type, Ingersoll-Rand.

Sinking

The shaft, 4 by 8 feet in cross section, had two compartments. It was cribbed for the first 15 feet and timbered with stulls and wallplates the remaining distance. Skids were constructed by nailing together 2- by 3-inch, 2- by 6-inch, and 2- by 4-inch lumber. Nearly all the timber used was cut from the claim.

In sinking the shaft, high and low ends were maintained in the bottom. An Ingersoll-Rand Jackhammer was used in drilling, and nine 4-foot holes were drilled in the high end in about 1 1/2 hours. The holes were loaded with five or six sticks of 1 1/8-inch, 45-percent Ajax No. 2 explosive, which was detonated by regular-delay, electric blasting caps.

Drifting

The drifts, 4 by 7 feet in cross section, were driven mostly in Boulder Creek granite. One man, using an Ingersoll-Rand airleg-type rock drill, drilled about fifteen 4- by 5-foot holes in 2 hours. A burn-cut round was drilled, and holes were loaded with five or six sticks of 1 1/8-inch Ajax No. 2 explosive, which were detonated with No. 6 blasting caps on 5-foot fuses. A hot-wire spitter was used.

The average drift advance was 4 feet per round. One man cleaned up the broken rock in 4 hours, which required loading thirty 10-cubic-foot bucketfuls and tramming them to the shaft on a bucket truck.

Pennsylvania Mine

From May through September 1956, the Pennsylvania shaft was sunk to a depth of 90 feet. At the same time an 18-foot crosscut and a 273-foot drift were driven.

The Pennsylvania vein strikes easterly and dips about 65° N. through Boulder Creek granite. Its width ranges from 1 to 30 inches. At about 20 feet below the surface the vein turned sharply away from the shaft, and the last 70 feet of the shaft was sunk in the footwall to maintain its original inclination.

Equipment at the shaft included:

1 hoist, driven by auto motor, Dodge 1936.
1 compressor, 125-c.f.m., gasoline-engine-driven, Jaeger.
1 hoisting bucket, 1,200-pound-capacity.
1 fan, 8-inch intake, Buffalo.
1 gasoline-driven engine, 14-hp., Wisconsin.
1 sludge pump, 35-g.p.m., Chicago Pneumatic.
1 rock drill, Thor Model 75.

Three men were employed at the Pennsylvania shaft--a hoistman-superintendent and two miners.

About 3,200 gallons of water was pumped from the mine each day. Broken rock was trammed underground over an 18-inch-gage track with 12-pound rails, in 12-cubic-foot-capacity end-dump-type mine cars. The load was dumped over a sheet-metal chute that guided the broken rock into the hoisting bucket.

Sinking

In sinking the Pennsylvania shaft high and low ends were maintained in the bottom. The shaft was 4 by 8 feet in cross section; and a round of nine 4-foot holes, drilled in the high end of the bottom, was required to break the ground. A Thor Model 75 drill was used to drill the holes, and each hole was loaded with five sticks of 1 1/8-inch, Dupont, 45-percent gelatin explosive, detonated with regular-delay electric blasting caps. Two men worked 1 1/2 hours to drill the round and 4 hours to clear the shaft bottom of broken rock.

The upper 15 feet of the shaft was cribbed; stulls and wallplates were used below the cribbing. Most of the timber used in the shaft was cut from a nearby hillside.

Drifting

The Thor rock drill used in sinking the shaft was mounted on an airleg and used for drifting. A 5- by 7-foot heading was driven, using an 18-hole, 4-foot, burn-cut round. Each hole was loaded with five to six sticks of 1 1/8-inch, Dupont, 45-percent gelatin explosive, detonated with No. 6 blasting caps on 6-foot-long fuses. A lead spitter was used to ignite the fuses. The drifting was done by two men who spent 2 to 3 hours drilling and 4 hours mucking.

Mine water was pumped into a tank installed in the upper part of the headframe. The water was used to wash the ore, thereby facilitating ore sorting.

Prospect Tunnel

The workings at this mine are extensive. A crosscut adit, 6 by 8 feet in cross section, was driven 1,420 feet in a southerly direction; a few short drifts, raises, and a winze extend from it. A long crosscut was being driven S. 72° E. from the end of the adit. Driving was begun in May 1956, and 876 feet of crosscutting through Boulder Creek granite had been completed February 28, 1957.

Eighteen-inch-gage track was provided; 20-pound rails were used in the adit; and 16-pound rails were used in the crosscut. Ventilation was controlled mechanically, and water for drilling was pumped from a winze in the older part of the mine.

Equipment included:

1 ventilating fan, 5-hp., Joy Air Vane.
1 pump, air-driven, Knowles duplex, No. 0.
1 compressor, 686-c.f.m., Gardner-Denver Model WBJ.
1 motor (for compressor) 440-volt, 125-hp.
1 locomotive, 1 1/2-ton, storage-battery-type, Atlas Type G.
1 charging unit for locomotive batteries.
1 rock loader, Eimco No. 12.
8 mine cars, 17-cu. ft., end-dump type.
1 airleg-type rock drill, Copco Pacific, No. 754.
1 airleg-type rock drill, Thor, No. 390.
2 airlegs, 5-foot.

Crosscutting

Two men had contracted to do all the work in the crosscut. A burn-cut round that consisted of twenty-five 5 1/2-foot holes was drilled with two airleg-type rock drills. The drill steel had a chisel bit. The holes were loaded with 1-inch Gelex No. 2 explosive that was detonated by No. 6 blasting caps on 8-foot fuses. A lead spitter was used to ignite the fuses. Fifty pounds of explosive was consumed for each round, and the average advance was 5 1/2 feet per round. Drilling, loading, and blasting required 4 hours' work; mucking and tramming required about the same time.

The cost per month for electric power to drive the compressor averaged $225. The contractors were paid $10 a foot advance for their labor.

Sunday Mine

The Sunday vein strikes east and dips steeply south. It was developed in the Sunday mine through a 200-foot-deep shaft and about 1,300 feet of drifts and crosscuts. A reverse fault that strikes N. 15° W. and dips southwest crosses the shaft and is believed to have controlled the occurrence of the large, replacement-type ore shoot found on the 150-foot level.

In 1956 two lessees repaired the caved collar of the shaft, installed 22 feet of cribbing, erected a new headframe, and dewatered the shaft to the 75-foot level.

Equipment and improvements at the shaft included:

1 winch with 1 1/2-hp. Wisconsin gasoline-driven engine.
1 rockdrill, Ingersoll-Rand Jackhammer.
2 stopers, Gardner-Denver.
1 mine car, 16-cu. ft.-capacity.
1 hoisting bucket, 600-lb.-capacity.
1 pump, sponge-type.

A drift was being driven on the 45-foot level. Bands of ferberite occur along the vein walls, which are schist, pegmatite, and aplite injection gneiss. A 3- by 7-foot stripping round, consisting of ten or twelve 3-foot holes, was drilled by one man in 1 hour, using a Jackhammer-type drill. Each hole was loaded with two sticks of 1-inch, Gelex No. 2, 45-percent explosive, which was detonated with No. 7 blasting caps on 6-foot fuses. A hot-wire spitter was used to ignite the fuses. In harder ground, three sticks of explosive were used per hole. Two men, working about 2 1/2 hours, cleaned the broken round, then dumped the waste into an open stope.

A small quantity of replacement-type ore that had been left by former operators was mined above the level. The production from the present operation has been small. The total production (1905-57) from the Sunday mine has been estimated as 6,260 units of tungsten trioxide.

Tungsten Mine

The Tungsten vein was discovered in 1900. It strikes N. 50° E. and dips 70° NW. The vein was developed through a shaft 370 feet deep, from which six levels, having about 3,600 feet of workings, had been turned. The Sunday vein extends into the Tungsten mine, where its strike is about N. 80° W. It intersects the Tungsten vein on the 80-foot level, 140 feet southwest of the Tungsten shaft. In 1952 after 50 feet of caved drift on the Tungsten vein to reach the Tungsten-Sunday intersection had been reopened, a drift was driven northwest along the Sunday vein, and a pipe of ore was found.

Water entered the mine at the rate of 24,000 gallons a day and required pumping 24 hours every other day. Track was 18-inch gage, with 12-pound rails. Broken ore was trammed to the shaft in a hoisting bucket, and waste was loaded into an 18-cubic-foot-capacity mine car and dumped into an open stope. Natural ventilation was aided by a connection with the Pioneer shaft. Compressed air was delivered to the working places through a 1 1/2-inch pipe. The walls of the vein are moderately hard; they are mostly biotite gneiss of the Idaho Springs formation and stand well.

Equipment included:

1 compressor, 400-c.f.m. reduced to 240-c.f.m., Ingersoll-Rand Imperial Type 10.
1 motor for compressor, 440-volt, 50-hp.
1 hoist, powered by 440-volt, 35-hp. motor, Denver Engineering Works.
1 pump, 40-g.p.m., 5-hp., duplex, Fairbanks-Morse
3 rock drills.
2 hoisting buckets, 15-cu. ft., with button dump.
3 mine cars.

Drifting

Fifteen hundred and ten feet of new drift was driven with an Ingersoll-Rand No. 2 drill that was mounted on a bar or column. Tungsten carbide insert threaded crossbits were used. The drift was 3 1/2 to 4 feet wide and 7 feet high. Eight to twelve 3 1/2-foot holes were drilled per round, and a V-cut was used. Each hole was loaded with two sticks of 1 1/8-inch, Gelex No. 2, 40-percent explosive, detonated with No. 6 blasting caps on 5-foot fuses. Fuses were ignited with a hot-wire spitter. Average advance was 3 feet per round; the drilling time averaged 4 hours; and mucking and tramming time, 8 hours. Only two men were employed; one operated the compressor and hoist, re-sorted the ore on the surface, and also assisted in mucking and tramming waste.

Stoping

During 1956 two men stoped a pipe of ore, which was cut in the Sunday drift on the 80-foot level, about 700 feet west of the Tungsten shaft. This ore shoot was stoped upward 200 feet on a 25° slope. Its average breadth was 8 feet, and its thickness ranged from 3 inches to 3 feet.

It required 1 1/2-hours to drill a stope round that consisted of eight to ten 3 1/2-foot holes. Each hole was loaded with two sticks of 7/8-inch, Gelex No. 2 explosive and was well-tamped. The charges were detonated in the same manner as in the drift rounds. Two men worked 4 hours to move the broken ore down the stope to the level and an additional 4 hours to load, muck, tram, and hoist it.

After the ore reached the surface, it was shoveled over a 1-inch screen. The coarse rock was carefully cobbed and sorted. The screenings and coarse ore were saved and the coarse waste--which amounted to about 40 percent of the rock that was handled--was discarded.

During 1956, 184 tons of ore was shipped to the Hoosier mill. The trucking cost was $2 and the milling cost $10 per ton. The concentrate assayed 61 percent WO_3 and contained 399.9 short-ton units of tungsten trioxide, which was sold for $55.10 per unit or $22,001.80.

Electric power cost $55.10 per month. The average monthly consumption of blasting supplies was: 100 pounds of explosive, 800 feet of fuse, and 300 caps During 1956 the expense for power, trucking, milling, and explosives totaled $3,368.

Data on drifts, shafts, and stopes that were driven in the mines of the Boulder County tungsten district in 1955-56 are shown in appendix 3.

ORE DRESSING AND CONCENTRATION

Gravity Concentration and Flotation

General

Ore was classified roughly by miners and operators as "soft" and "horn" ore. Soft ore is friable, coarsely crystalline ferberite ($FeWO_4$) that occurs in breccia and vein quartz and is amenable to gravity concentration. Horn ore comprises extremely fine-grained crystals of ferberite disseminated through contemporaneous fine-grained quartz hornstone. Horn ore is difficult to concentrate; it requires fine grinding, causes wear on equipment, and slimes excessively. Most ores from the area were partly the "horn" variety.

The first gravity-concentration mill to beneficiate ferberite ores was built in Gordon Gulch in 1900. Since then at least 36 gravity-concentration mills, 2 tungstic-acid plants, 1 synthetic-scheelite plant, 1 ferrotungsten plant, and 1 magnetic-separator plant have been operated in the district.

During the past 2 years the Herald and Domino mills were dismantled; the Joe Smith mill burned and was not rebuilt. The new Upper Good Friday mill was constructed near the April Fool shaft. In 1956 there were six tungsten mills in the area (fig. 3). Milling equipment had changed since 1900, but the tried practices of step crushing, classifying, jigging, and tabling were still in use. Stamps had given way to rolls, ball mills, and rod mills, and vanners had been replaced with slime tables. Flotation was first tried with success in 1941. In 1956 a flotation unit was being operated in only one mill. Cross-belt magnetic separators were used to upgrade concentrates, and small Polzin pulsating jigs, treating table tails and middlings, had increased recovery. Locations of mills and plants are shown in figure 3.

Wah Chang Mill

The Wah Chang mill (Teal mill) (fig. 6) was operated one shift a day by five men and treated only custom ore. The flowsheet differed from that of the old Teal mill as follows: Another receiving bin, a double sampler was added; sand-table middlings and tails were rerouted to a scavenger table, and the rag tables were eliminated. The Teal leach plant was replaced by a three-cross-belt Stoll magnetic separator. Ten tons of ore were concentrated in an 8-hour shift. Water was purchased from the city of Boulder.

Milling

The customers' ore was weighed and dumped into one of four receiving bins. Ore was then fed by belt conveyor to a shaking grizzly, and the oversize passed through a 9- by 16-inch jaw crusher. The screened and crushed products were then elevated, and a sample cut was taken with a Snyder double sampler. The reject was passed over a 3- by 6-foot vibrating screen, the oversize passed through a set of 27- by 14-inch rolls, and the undersize and rolled product went to a fines bin. Fines were then fed by a belt feeder into a second elevator and raised to a trommel with 1/16-inch openings. The minus-1/16-inch

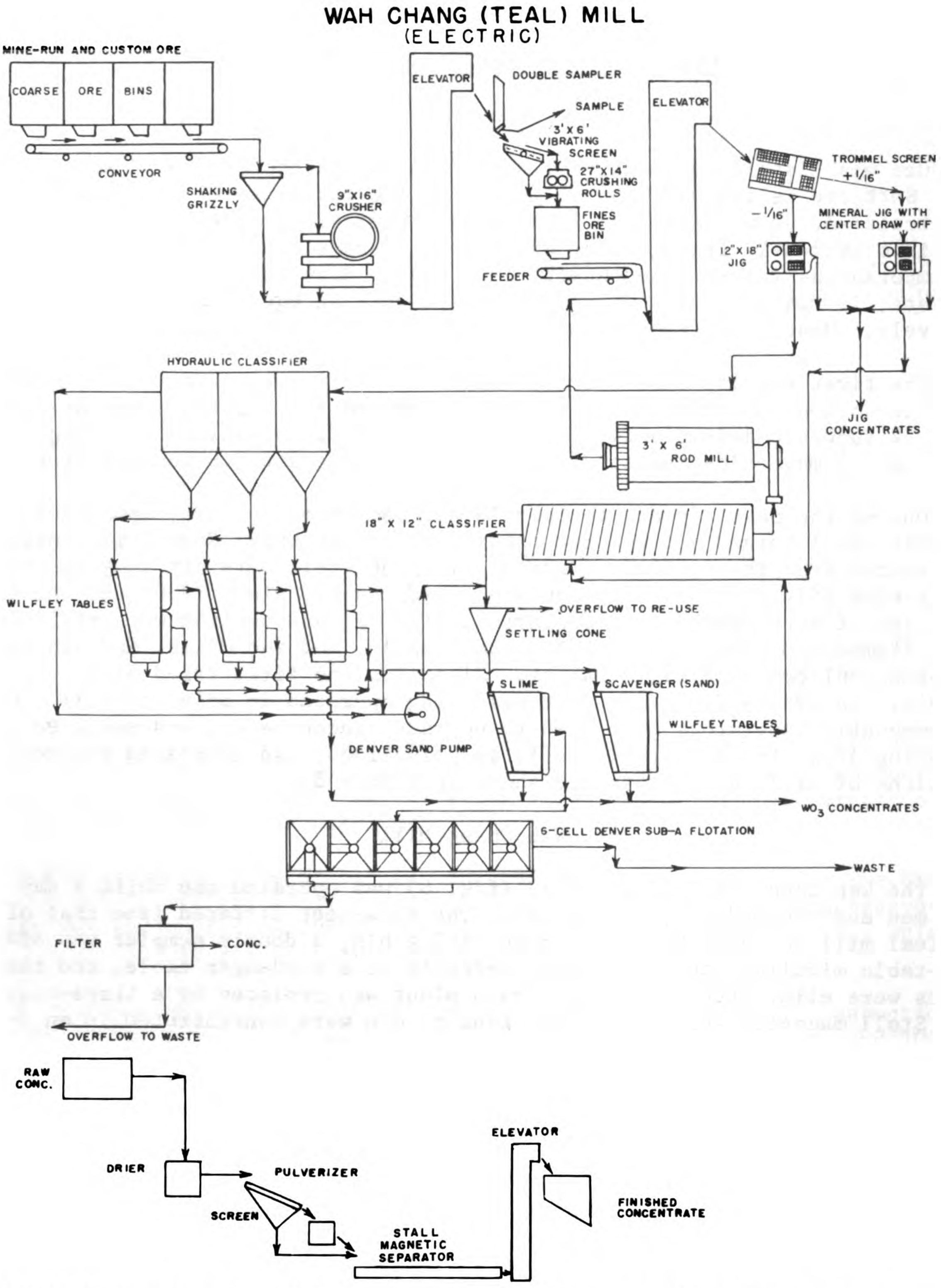


FIGURE 6. - Flowsheet of the Wah Chang (Teal) Tungsten Mill, Boulder County, Colo.

product passed through a 12- by 18-inch two-compartment Mineral jig, from which the overflow went to a hydraulic classifier. The trommel oversize went to a second Mineral jig and the jig tailing to an Akins classifier. The Akins-classifier oversize went to a 3- by 6-foot rodmill for regrind and returned to the trommel. The classified material in the hydraulic classifier passed over three standard Wilfley tables. The middlings from the Wilfley tables passed to a scavenger table, and the middlings and tails from the scavenger table were sent back to the Akins classifier. The tails from the three Wilfley tables, together with the overflow from the Akins and hydraulic classifiers passed over a slime table, and the tails and middlings from the slime table went to a six-cell, Denver Sub-A flotation unit. The low-grade flotation concentrate was filtered and sent to the company plant at Glen Cove, N. Y., for further treatment. The raw concentrates from the jigs and tables were dried and screened; the coarse was pulverized and the entire concentrate treated with a Stoll, three-crossbelt magnetic separator.

Upper Good Friday Mill

The Upper Good Friday mill (fig. 7) was built in 1955 at the April Fool shaft. The shaft bucket dumped directly into the mill bin. All ore was washed, screened, and sorted. The flowsheet consisted of crushing and grinding units, jigs, sand tables, a slime table, and a More magnetic separator. Two men were employed on each shift.

Mill capacity was 30 tons per regularly operated 16-hour day. No custom milling was done.

Milling

The ore was dumped from the mine bucket into a 10-ton bin, from which it passed over a 3/4-inch grizzly. The oversize went over a 16-inch by 10-foot picking belt, where waste was picked out. From the picking belt the ore passed through a 12- by 28-inch Universal jaw crusher. The crushed ore and the grizzly undersize passed through McFarlane 12- by 16-inch rolls, set at 3/8 inch, and then into an Akins 30-inch classifier, which was used as a dewaterer. The fines then passed into a 16- by 16- by 7-foot fines-ore bin. The ore was fed from the bin by an Eggers plunger-type feeder into an 8-foot by 24-inch trommel having 1/4-inch openings. The trommel oversize passed through a Denver Equipment 14- by 12-inch jig into an Akins 14-foot by 36-inch classifier used as a dewaterer. The trommel undersize went through another jig of the same type to the Akins classifier. From this classifier the ore passed through a set of 10- by 12-inch McFarlane rolls into an 8-foot by 24-inch trommel with a 12-mesh screen. The trommel oversize went to a 30-inch by 48-inch ball mill and thence to a Wilfley table. The trommel undersize passed over a regular-size Wilfley sand table. The table tails and middlings went to a double hydraulic classifier, from which the slimes went to a 4- by 12-foot slime table, and the coarse was treated in a 6- by 12-inch Polzin pulsating jig. The concentrates from the jigs and tables were dried, passed through a set of 5- by 5-inch rolls, and treated in a More 4-crossbelt magnetic separator.

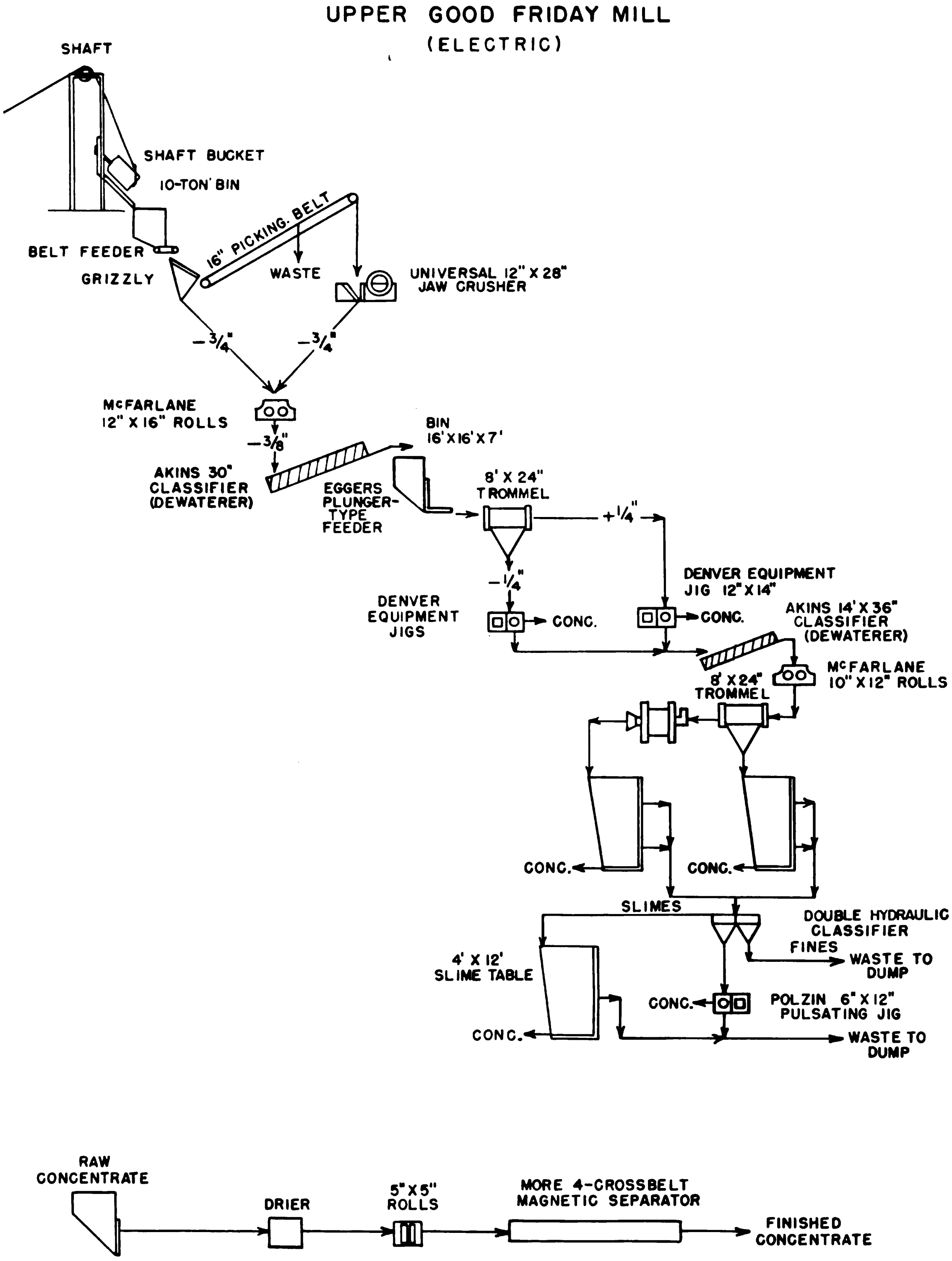


FIGURE 7. - Flowsheet of the Upper Good Friday Tungsten Mill, Boulder County, Colo.

Lower Good Friday Mill

The Lower Good Friday mill (fig. 8) was near the portal of the lowest adit. The mill flowsheet had remained virtually the same for the past 4 years. Mine-run ore was dumped into the mill bin and then screened, washed, and handsorted.

The mill was operated 16 hours a day. Three men were employed--one on the picking belt and one each shift to operate the mill. The mill capacity was 20 tons per 16-hour day. No custom milling was done.

Milling

The crude ore was dumped from the mine cars into a 10-ton-capacity crude-ore bin at the head of the mill. It was fed from the bin over a 30- by 36-inch grizzly set at 3/4 inch. The grizzly oversize passed to a 30- by 30-inch shaking screen with 3/4-inch openings. The shaking-screen oversize passed to a 20-inch by 40-foot picking belt and then through a 2-M Universal 12- by 18-inch crusher, which crushed it to 3/4 inch. The grizzly and shaking screen undersize and the crushed ore went to a 30-ton fines bin, from which it was fed by a worm feeder into a set of 10- by 16-inch McFarlane rolls. The ground-up ore then went into a double-screen 36- by 72-inch trommel. The trommeled minus-1/8-inch material passed through a single-compartment, 8- by 12-inch, Mineral jig; the trommeled minus-1/4-inch material passed through a two-compartment, 8- by 12-inch, Mineral jig; and the trommeled oversize and the tails from the two jigs were sent to a 3- by 4-foot ball mill. The ball mill discharged into a small trommel with a 1/16-inch screen, which was in closed circuit with the ball mill. The trommeled minus-1/16-inch material passed over a No. 6 Wilfley sandtable. The middling from the sandtable passed through a 6- by 8-inch single-compartment Mineral jig. The concentrates from the jigs and table were sacked and sent for upgrading on the More magnetic separator at the Upper Good Friday mill.

Hoosier Mill

The Hoosier mill (fig. 9) has had the same flowsheet since 1952. All ore was passed through one of two sorting plants before being put in the mill bin. The operators produced ore from the Hoosier, Clyde, and Phillip Extension mines and from some of their dumps and tailings piles. Custom ore was also treated in the mill for $10 a ton, and the concentrate recovered was returned to the shipper. Milling capacity was 10 tons a shift; water consumption was 80,000 gallons a shift (8,000 gallons a ton); and electric-power costs were about $90 a month. A TD-9 loader was used to load tailings and dump material into trucks.

The plant was considered by local shippers to have been operated efficiently; two men were employed in the mill.

Milling

Ore was trucked from the ore-sorting plant to a 25-ton-capacity crude-ore bin at the head of the mill. From the crude-ore bin the ore was passed over a 1 1/4-inch grizzly and through a 10- by 16-inch jaw crusher. Grizzly undersize

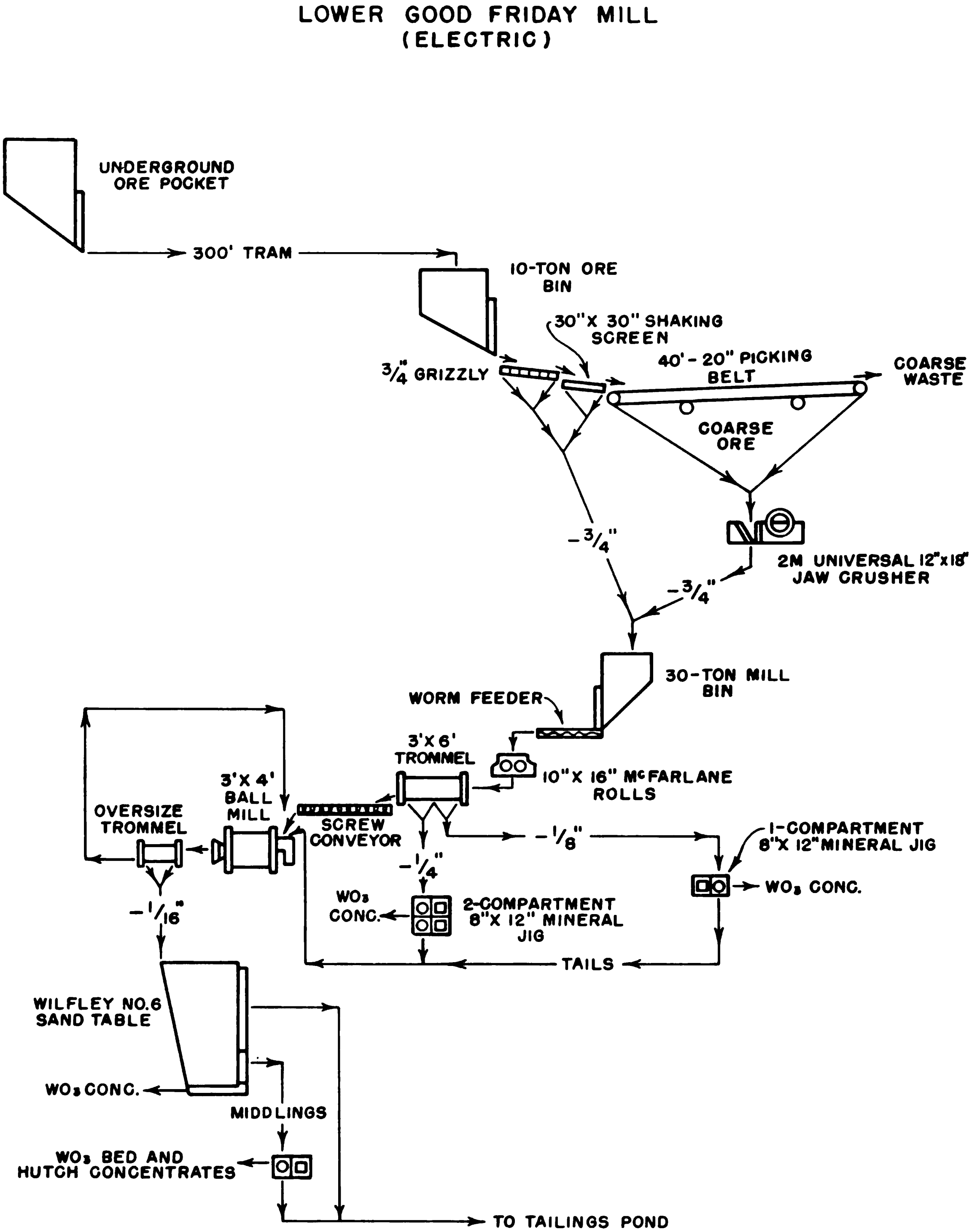


FIGURE 8. - Flowsheet of the Lower Good Friday Tungsten Mill, Boulder County, Colo.

HOOSIER MILL
(ELECTRIC)

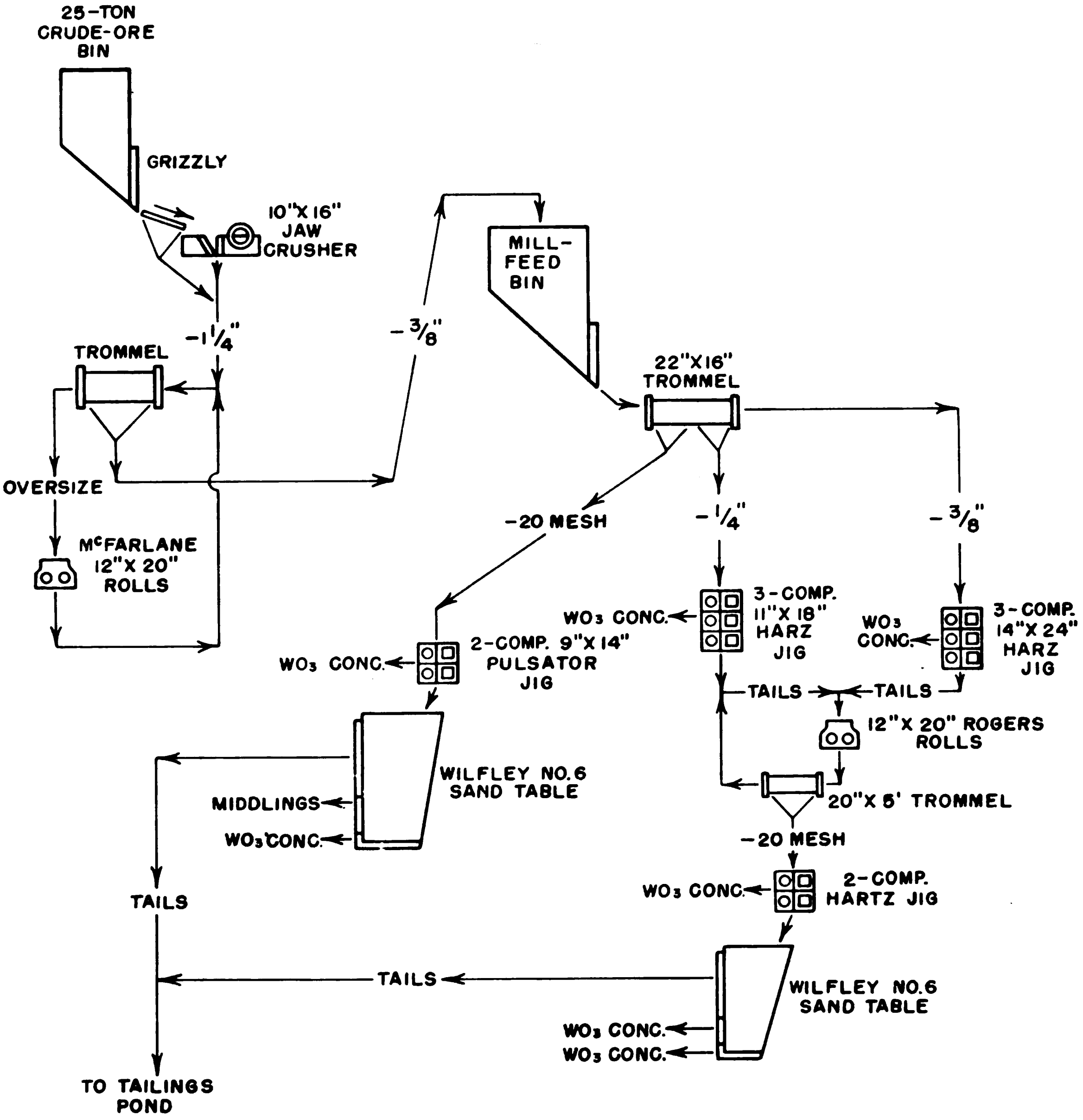


FIGURE 9. - Flowsheet of the Hoosier Tungsten Mill, Boulder County, Colo.

and the crushed ore went to a 6-foot by 30-inch trommel with 3/8-inch openings. Trommel oversize was run through a set of 12- by 20-inch McFarlane rolls and returned to the trommel, and the undersize (minus-3/8-inch) was elevated to a mill-feed or fines-ore bin. Ore from the fines bin was fed into a 6-foot by 22-inch double-screen trommel, and the minus-20-mesh trommel product was sent over a two-compartment 9- by 14-inch pulsator jig to a No. 6 Wilfley sandtable. The table concentrate and middling were saved separately. Table tails went to the tailing pond. The minus-1/4-inch trommel product passed over a three-compartment 11- by 18-inch Harz jig, and the trommel oversize went to a three-compartment 14- by 24-inch Harz jig. Tails from both Harz jigs went through a set of 12- by 20-inch Rogers rolls to a 5-foot by 20-inch trommel with a 20-mesh screen. The trommel oversize was returned to the Rogers rolls, and the undersize went through a two-compartment jig from whence the tails went to a No. 6 Wilfley sand table. Table concentrates were dried in a pan drier, and the tailings went to the pond.

Cold Spring Mill

The Cold Spring mill (fig. 10), formerly the Wolf Tongue mill of Hetzer Mines, Inc. (1) had nearly the same flowsheet as it had in 1953. The only change was the addition of a small 6- by 12-inch Polzin pulsating jig to treat the tailing discharge from each of two sandtables. The plant was operated usually on 1 shift a day, 5 days a week; and the capacity was 15 tons a shift. Milling required 350 gallons of water per minute, which was pumped from Middle Boulder Creek, with a Fairbanks-Morse centrifugal pump, driven by a 20-hp. motor. The electric-power bill for the mill was about $400 a month or about $15 a working shift.

Five men were employed in the mill during January 1956, but the normal crew was two or three men. Ore from the Cold Spring mine and some lessees' and custom ores were treated.

Milling

The crude ore was dumped into one of three receiving bins at the head of the mill. A pan feeder fed the ore from the bin onto a 6-foot by 30-inch grizzly with 1-inch openings. Oversize went to a Pacific 14- by 20-inch jaw crusher, and the entire minus-1-inch product was elevated to a 2- by 4-foot 1/2-inch vibrating screen. Oversize from the screen went through a set of McFarlane 16- by 36-inch rolls and was again elevated to the vibrating screen. Undersize passed through a Vezin sampler and was then stored in a large fines-ore bin.

High-grade ore was dumped into a small receiving bin. The ore was passed from the receiving bin through a 6- by 12-inch jaw crusher set at 3/4 inch and then through a set of 6- by 16-inch Colorado Iron Works rolls. The rolled product, of 1/4-inch size, was sampled with a Vezin sampler, and the ore was then sacked and stored in lots. The grade of these lots ranged from 15- to 60-percent WO_3; most of these lots were mixed with concentrate shipments.

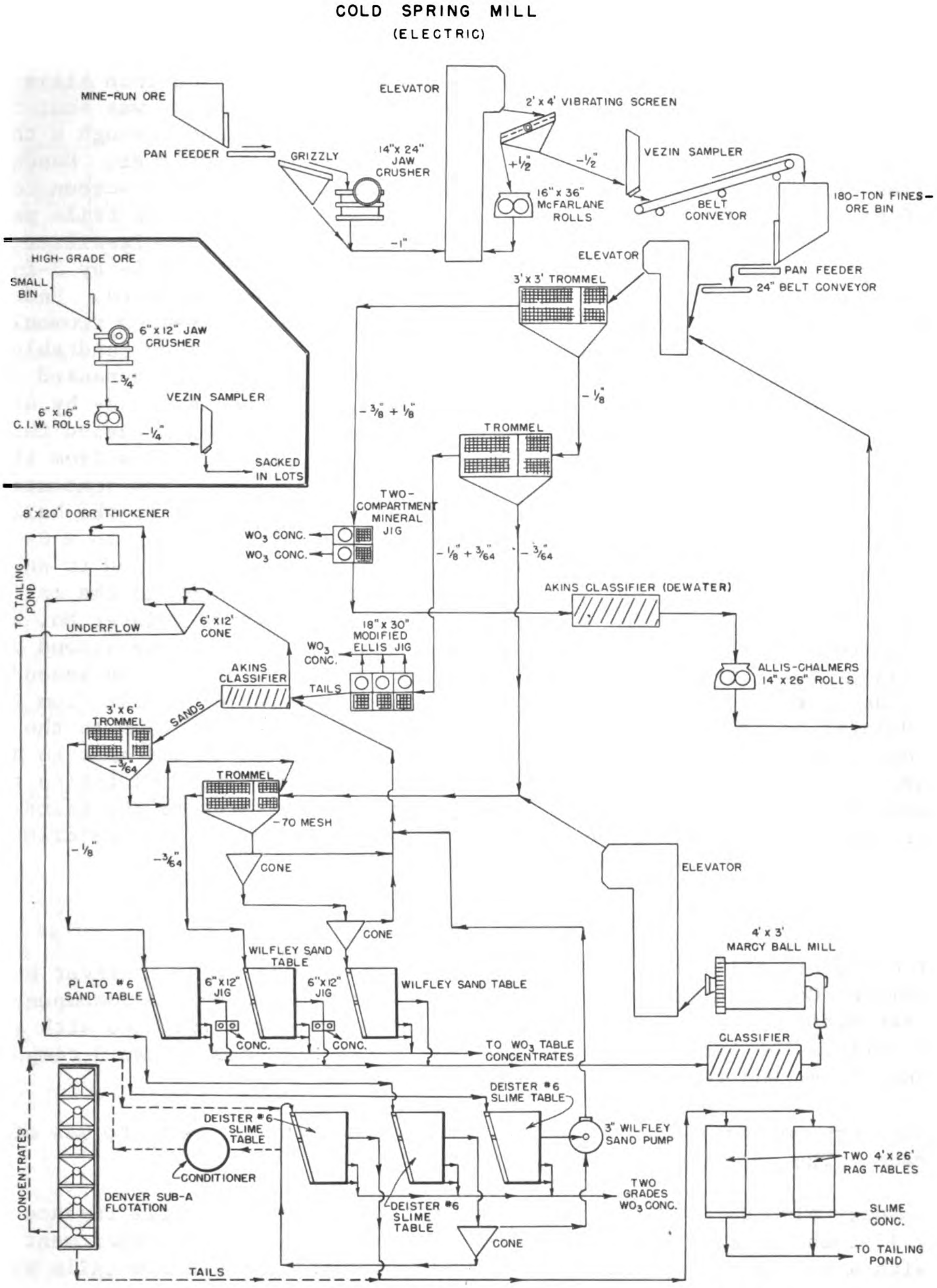


FIGURE 10. - Flowsheet of the Cold Spring Tungsten Mill, Boulder County, Colo.

Ore from the fines bin was fed onto a 24-inch belt conveyor and then elevated to a 3- by 3-foot trommel with a 1/8-inch screen. The trommel oversize passed through a two-compartment, 25- by 36-inch, Mineral jig to an Akins classifier for dewatering, then crushed in a set of 14- by 26-inch Allis Chalmers rolls and returned to the trommel. Trommel undersize was sent to a second trommel with a 3/64-inch screen. The oversize passed through a three-compartment 18- by 30-inch Ellis jig to a second Akins classifier. Sands from this classifier passed through a third trommel with a 3/64-inch screen to a No. 6 Plato sandtable. Two table concentrates were made. Table tails passed through a 6- by 12-inch Polzin pulsating jig to a third Akins classifier, which was used as a dewaterer. The dewatered tails were ground in a 4- by 3-foot Marcy ball mill and sent to a fourth trommel with a 70-mesh screen. Undersize from the third trommel (minus-3/64-inch) also went to the 70-mesh trommel. The oversize from the 70-mesh trommel passed to a No. 6 Wilfley sandtable, where two concentrates were made. Tails from the sandtable were passed over a 6- by 12-inch Polzin pulsating jig, dewatered, and sent to the 3- by 4-foot ball mill for regrind. Undersize from the 70-mesh trommel was passed through two settling cones to a third Wilfley sandtable, and the overflow from the settling cones was returned to the second Akins classifier. Two concentrates were made on the Wilfley table, and the table tails were sent to the ball mill for regrind. Overflow from the second Akins classifier was sent to a 6- by 12-foot settling cone. The overflow from the settling cone flowed to an 8- by 20-foot Dorr thickener. The Dorr thickener overflow was sent to the tailing pond, and the thickened slime was sent to a second of three Deister No. 6 slime tables. Two table concentrates were made. Tails from the second slime table passed to a settling cone. The overflow was returned to the second Akins classifier and the overflow to a third Deister table. Tails from the third Deister table went to two 4- by 26-foot rag tables and then to the tailing pond. Sometimes the tail from the second Deister table was sent to a conditioner and then to a six-cell Denver Sub-A flotation unit. Flotation tails were sent to the rag tables, and the flotation concentrates to the third Deister table. The various jig, table, and slime concentrates were dried and mixed to produce the most profitable marketing grade.

Cowdery Mill

The Cowdery mill (fig. 11) was operated in 1954 and 1955 to treat horn ore from the Copeland mine. Some of the equipment shown on the accompanying flowsheet differs from that first used. A stamp mill was replaced with a set of rolls. The two-compartment Harz jig was replaced with two 3-compartment Harz jigs, and rag tables were eliminated.

Recovery was very poor after the changes, and the concentrate was of very low grade. The operation was soon suspended.

Cowdery planned to revert to the former flowsheet. He will replace the 10- by 12-inch rolls with five 1,250-pound stamps, the two 3-compartment Harz jigs with a single two-compartment Harz jig, and the slime-table tails will be passed over two 4- by 25-foot rag tables.

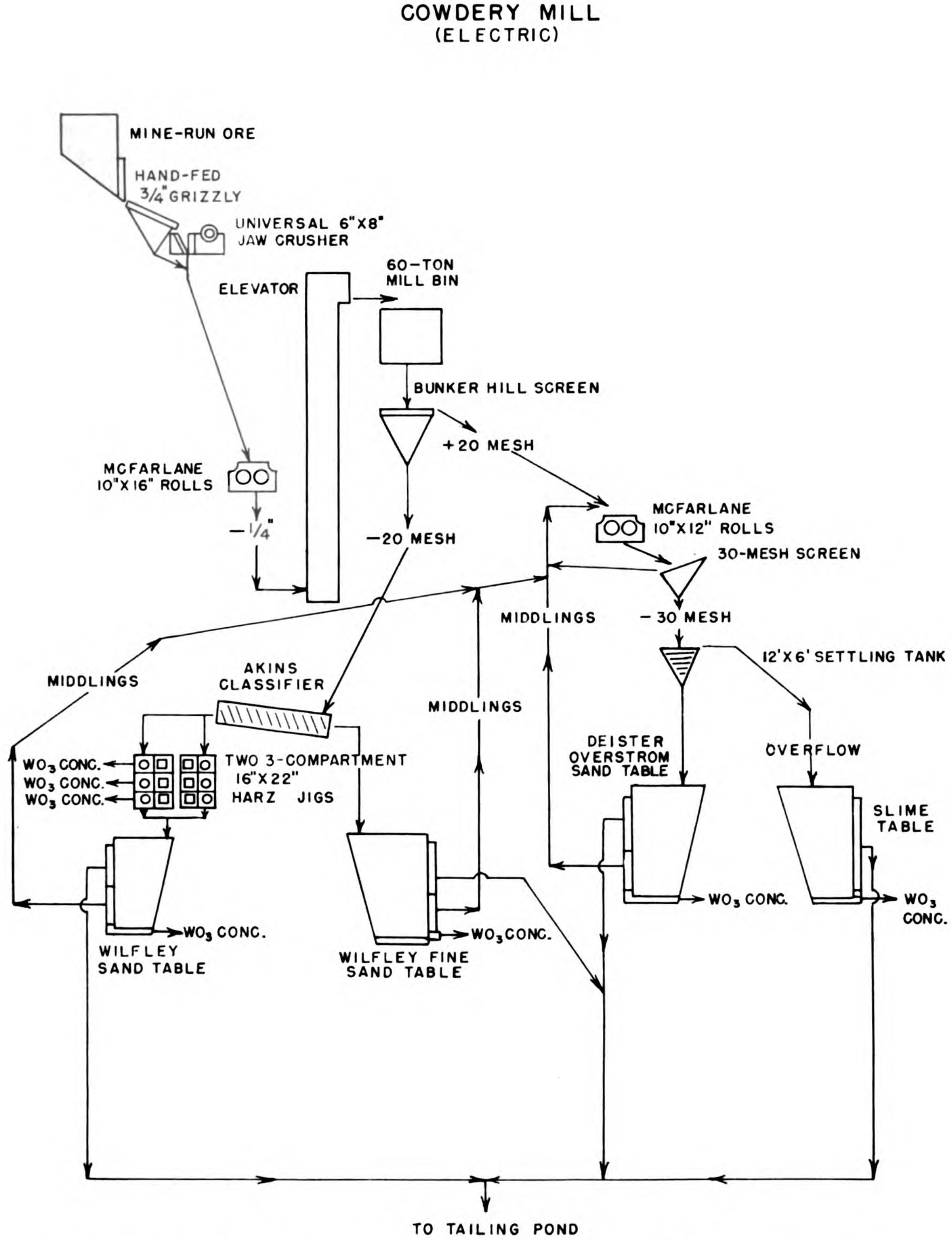


FIGURE 11. - Flowsheet of the Cowdery Tungsten Mill, Boulder County, Colo.

Milling

The ore was dumped from a truck into a receiving bin at the head of the mill, from which it was handfed over a 3/4-inch grizzly into a 6- by 8-inch Universal jaw crusher. Material from the grizzly and crusher was then passed through a set of 10- by 16-inch McFarlane rolls, and elevated to a 60-ton-capacity fines-ore bin. Ore from the fines bin was passed over a 20-mesh Bunker Hill screen. Oversize from the 20-mesh screen was sent through a set of McFarlane 10- by 12-inch rolls to a 30-mesh vibrating screen. Screen oversize was returned to the rolls; the undersize passed into a 12- by 6-foot settling tank.

The underflow from the settling tank went to a Deister-Overstrom sandtable. Sandtable middlings were returned to the rolls to be reground; the tailings went to the pond. Overflow from the settling tank went to a Deister-Overstrom slime table, from which the tailings went to the pond.

The minus-20-mesh product from the Bunker Hill screen was sent to an Akins classifier. Classifier sands were split over two 3-compartment 16- by 22-inch Harz jigs. Jig tails were sent to a Wilfley sandtable and the table tails to the tailing pond. Table middlings were returned to 10- by 12-inch rolls. The classifier overflow was passed over a Wilfley fine-sand table. Table tails flowed to the tailing pond, and the middling was returned to the 10- by 12-inch rolls. The concentrates from the two jigs and four tables were dried and shipped.

Chemical Plants

General

Operation of the leaching plant at the Teal mill was discontinued in 1955 after the mill was purchased by Wah Chang Corp. The Vanadium Corporation of America, while leasing the Hetzer mill, spent much time building a chemical (scheelite) plant, but it burned before it was completed. The Cold Spring Mining Co., using the same site, worked on a chemical plant in 1955-56, apparently without success. Operations were temporarily suspended in December 1956 and the two men that were employed in the plant were transferred to the mill. The owners of the Manyon mine worked on a chemical process in 1956, but their results were not made known. Apparently, Tungsten Refining, Inc., was the only successful producer of tungsten products, other than ferberite concentrates, in the area.

Tungsten Refining, Inc., Scheelite Plant

The Tungsten Refining, Inc., scheelite plant (fig. 12) was in Boulder. The flowsheet included grinding, adding chemicals and roasting, leaching, filtering, precipitating, washing, and drying. The operator contemplates installing several labor-saving devices, provided a long-range WO_3 buying program is established by the Government.

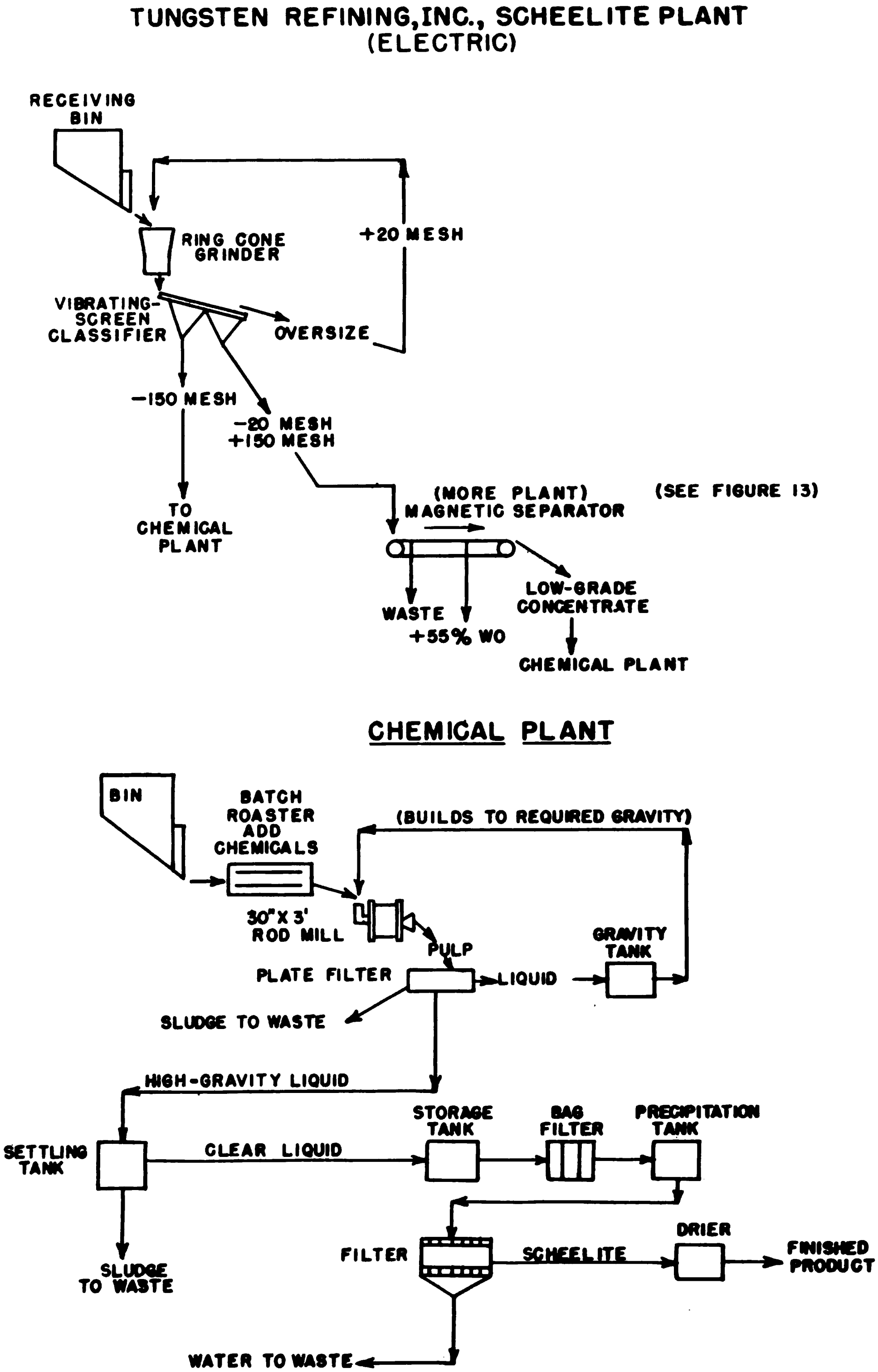


FIGURE 12. - Flowsheet of the Tungsten Refining, Inc., Scheelite Plant, Boulder County, Colo.

The tungsten concentrate was ground with soda ash and roasted in a batch furnace; the sinter was wet-ground in a ball mill. The ball-mill pulp passed through a plate filter, and the alkaline filtrate recirculated through the ball mill until it was built up to the required gravity. The high-gravity liquid was passed through a settling tank to a clear-liquid storage tank, from which it passed through a bag filter to a precipitation tank where calcium chloride was added. The reaction of the chloride with the tungsten solution caused the pH to drop. When the pH was about seven, the scheelite was precipitated on a double-plate filter and washed.

The precipitate was placed in a gas-fired pan drier. When dry, the scheelite was ready for market. Sulfur was removed by the high-temperature roast, and phosphorus was removed in the circuit by adding a chemical.

The roaster was a source of trouble. Experimenting resulted in developing a gas-fired batch furnace with a high-test Denver Fire Brick Co. hearth covered with a heavy metal sheet.

The small ball mill was made of 3/8-inch Jalloy steel. It had no liners, but 1 1/8-inch pieces of drill steel, laid parallel and 8 inches apart, were welded lengthwise the Jalloy steel shell.

Production in 1955 was 5,143 units of tungsten trioxide.

Magnetic Separation

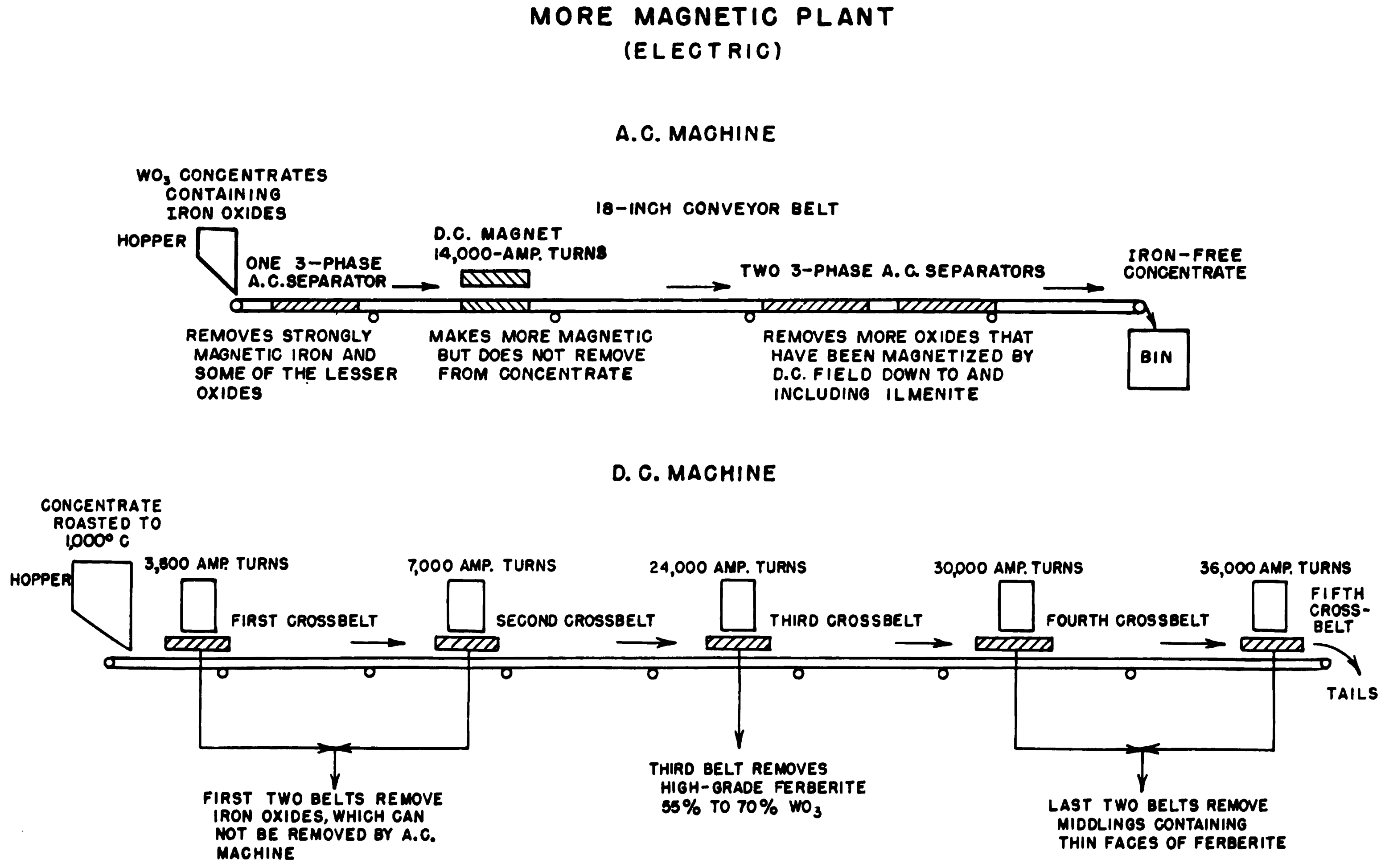
General

Magnetic separators have been used to upgrade tungsten ores for 40 years. However, crossbelt magnetic separators first came into use in the district about 1947. At the Wah Chang mill there was a three-crossbelt Stoll magnetic separator; at the Upper Good Friday mill a four-crossbelt More magnetic separator was in use; and the Ford plant had a one-crossbelt More magnetic separator. This equipment aided materially in upgrading concentrates by removing iron and silica.

More Magnetic Plant

The More magnetic plant (figs. 12 and 13) was in the building used by Tungsten Refining, Inc., in Boulder. The plant contained a three-pole alternating-current magnetic separator, by which magnetic materials were moved readily off the side of an 18-inch belt; an electromagnet also was installed to magnetize the ore particles. The plant also contained a five-crossbelt, direct-current separator by which roasted concentrates were treated by passing them under five electromagnets of different intensities, ranging from 3,600 to 36,000 ampere turns. The crossbelts at each set of magnets removed the magnetic material from the traveling conveyor belt.

The plant was looked upon with favor, especially by operators working dumps and float beds, who desired to upgrade their concentrates by removing the iron.


MORE MAGNETIC PLANT
(ELECTRIC)
A.C. MACHINE
WO3 CONCENTRATES CONTAINING IRON OXIDES
HOPPER
18-INCH CONVEYOR BELT
ONE 3-PHASE A.C. SEPARATOR
D.C. MAGNET 14,000-AMP. TURNS
TWO 3-PHASE A.C. SEPARATORS
IRON-FREE CONCENTRATE
REMOVES STRONGLY MAGNETIC IRON AND SOME OF THE LESSER OXIDES
MAKES MORE MAGNETIC BUT DOES NOT REMOVE FROM CONCENTRATE
REMOVES MORE OXIDES THAT HAVE BEEN MAGNETIZED BY D.C. FIELD DOWN TO AND INCLUDING ILMENITE
BIN
D.C. MACHINE
CONCENTRATE ROASTED TO 1,000° C
HOPPER
3,600 AMP. TURNS
FIRST CROSSBELT
7,000 AMP. TURNS
SECOND CROSSBELT
24,000 AMP. TURNS
THIRD CROSSBELT
30,000 AMP. TURNS
FOURTH CROSSBELT
36,000 AMP. TURNS
FIFTH CROSS-BELT
TAILS
FIRST TWO BELTS REMOVE IRON OXIDES, WHICH CAN NOT BE REMOVED BY A.C. MACHINE
THIRD BELT REMOVES HIGH-GRADE FERBERITE 55% TO 70% WO3
LAST TWO BELTS REMOVE MIDDLINGS CONTAINING THIN FACES OF FERBERITE

(SEE FIGURE 12)

FIGURE 13. - Flowsheet of the More Magnetic Tungsten Plant, Boulder County, Colo.

Scavenging Plants for Float Beds and Dump Ore

General

Many thousand tons of rock from the better grade dumps were milled before 1956 in the tungsten mills of Boulder County. One entire Rodgers mine dump was sold to the Government stockpile; it averaged 0.98 percent WO_3 as shipped. However, many dumps were too low grade to pay for treatment in a tungsten mill, where milling costs averaged about $12 a ton. These dumps contained as much as 0.5 percent WO_3, and recovery from the better dumps averaged about 0.2 unit of WO_3 per ton. With such a low recovery, a cheap scavenging or scalping method was required, wherein no crushing and grinding was done. No attempt was made to operate during winter, after the ground froze.

Cobb-Weldon Float and Dump Operations

The Cobb-Weldon operation was the largest of the three in the district. Surface float and dumps were screened and hand-sorted. The product was trucked to the plant and jigged (fig. 14). About 10,000 tons of float beds and dumps had been worked each year for the past 5 years. Equipment consisted of a 5/8-yard International TD-6 loader, a small grizzly, a conveyor, a trommel, a truck, and a jigging plant. The capacity of the plant was 80 tons a day. About half of the material was sorted out as waste at the trommel screen. Operations were suspended during cold weather.

Six men were employed: Two worked at the float bed or dump; one drove the truck; and three worked in the plant.

The costs of the dump and plant operation were as follows:

	Per day	Per ton
Dumps		
Labor (3 men) (includes overtime and taxes)	$42.90	$0.54
Gasoline	5.50	.07
Repairs	15.00	.19
Lubrication	1.00	.01
Amortization	9.70	.12
Supervision (part time)	5.90	.07
Total	80.00	1.00
Plant		
Labor (3 men) (includes supervision)	42.90	0.54
Power	4.00	.05
Lubrication	1.00	.01
Repairs	2.00	.025
Amortization	9.70	.12
Total	59.60	.745
Grand total	139.60	1.745

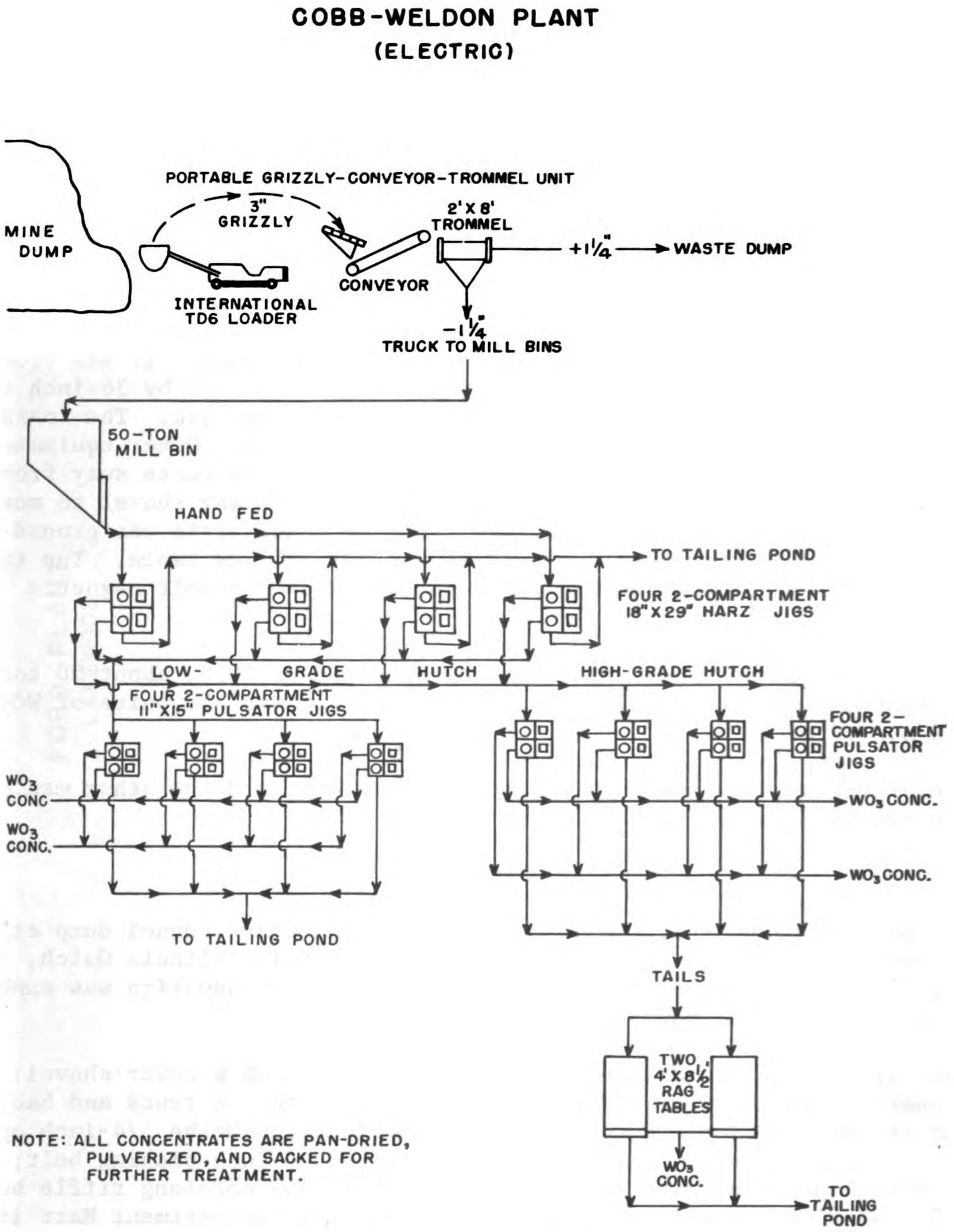


FIGURE 14. - Flowsheet of the Cobb-Weldon Tungsten Plant, Boulder County, Colo.

About 50,000 tons has been run through the plant. Average recovery had been about 4 pounds of 50-percent concentrate or 2 pounds of WO_3 per ton.

Ford Plant

The Ford plant (fig. 15) at Lakewood near the junction of Sherwood Gulch and North Boulder Creek was operated about 30 days in 1956, but Ford expected to operate 8 months in 1957.

The mine is in Sherwood Gulch about one-half mile above the plant. The surface wash averages about 6 feet thick. The wash contained tungsten and a little gold. A Bucyrus-Erie 1/2-yard dragline was used to load the wash into a 1 1/2-ton Ford dump truck or a 2-ton Chevrolet dump truck. It was trucked to a hopper at the plant, and was then fed through an 8-foot by 36-inch trommel screen with 1-inch openings to a 36- by 36-inch Bendelari jig. The coarse material from the trommel passed to a 24-inch picking belt. Other equipment included a 14-inch, 60-foot-long steel launder to carry the waste away from the jig; a Caterpillar D-4 bulldozer; and a 4/10-yard Quick Way shovel to move the waste from the plant site and the creek. The jig concentrate was ground in an 18- by 36-inch ball mill, then passed over a small Wilfley table. The table concentrate was dried, and put through a More single-crossbelt magnetic separator.

During the 30 days that the plant was operated in 1956, about 50 tons was treated each day or a total of 1,500 tons. Recovery was 250 units of WO_3 and about 12 ounces of gold.

One of the two men employed worked at the plant, and the other man operated the dragline and drove the truck.

Pastore Plant

The Pastore plant (fig. 16) was erected on the Clark tunnel dump at Tungsten. Feed for the plant came from a placer deposit in Illinois Gulch, the Illinois dump, and a number of other dumps. The 1957 production was expected to come from float beds near the Giggey Ranch.

The material was loaded upon a Kolman conveyor with a power shovel; then passed over a 3-inch screen. The fines were loaded into a truck and hauled to a bin at the plant. The ore was fed from the bin through the 3/4-inch openings of a trommel screen. The coarse material passed to a picking belt; the minus-3/4-inch material went into one of two 4- by 50-foot-long riffle boxes. Material caught on the riffles was run through a four-compartment Harz jig. The Harz jig was to be replaced with two 18- by 30-inch, Pastore, side-pulsating, diaphragm jigs of novel design.

Four men were employed. In 1955 production was 554 units of tungsten trioxide.

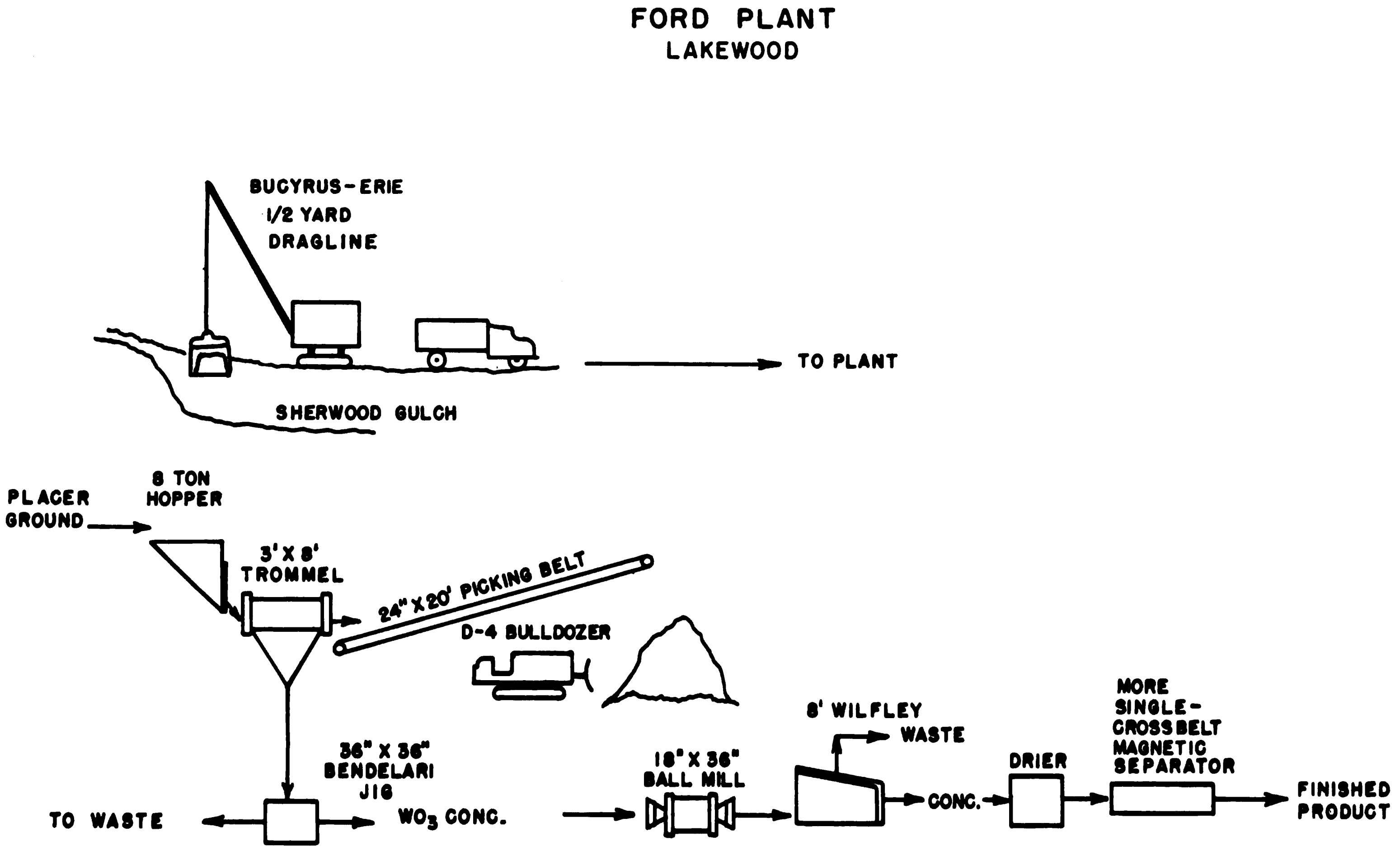


FIGURE 15. - Flowsheet of the Ford Tungsten Plant, Boulder County, Colo.

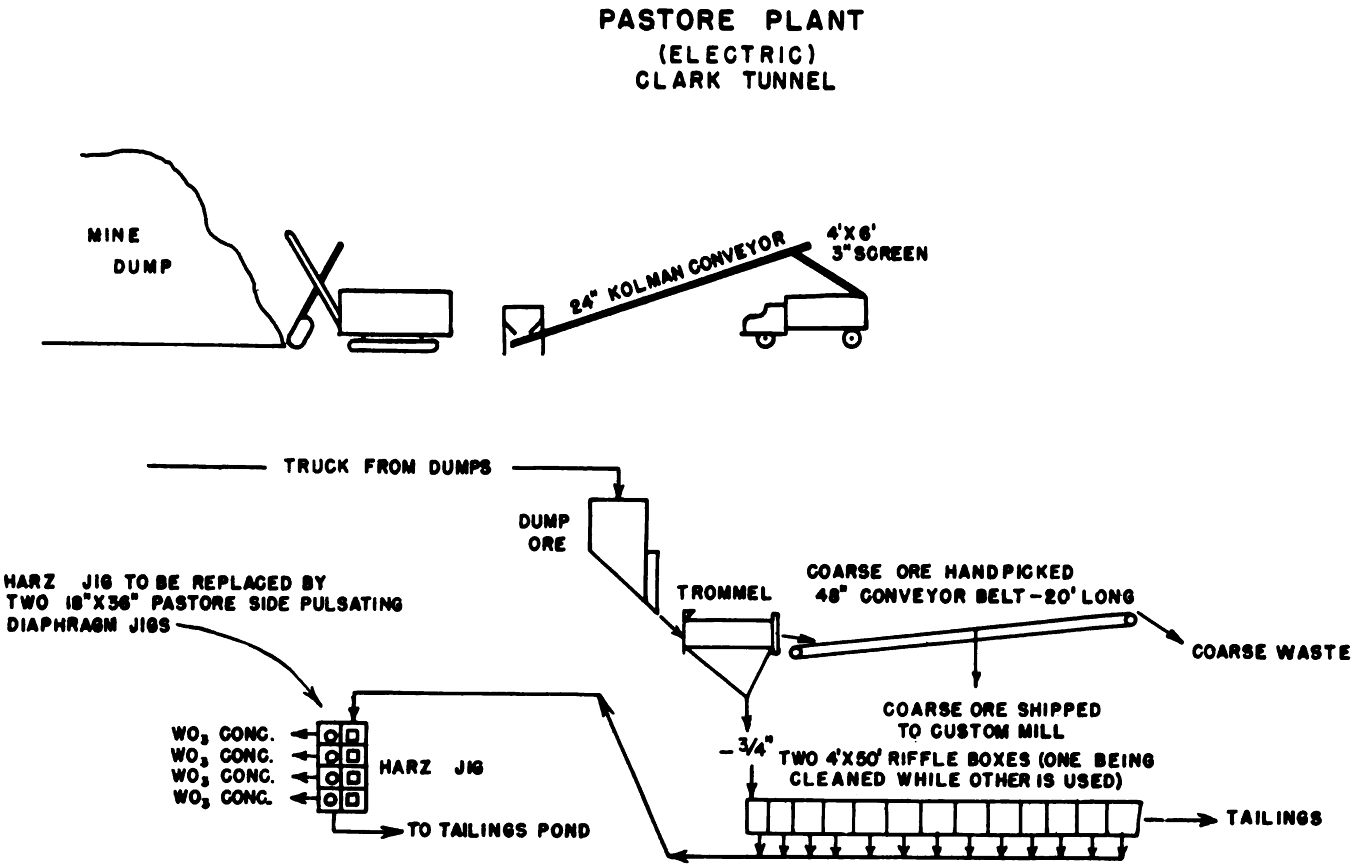


FIGURE 16. - Flowsheet of the Pastore Tungsten Plant, Boulder County, Colo.

Bonanza Plant

The plant was just below the Bonanza No. 2 mine in Bonanza Gulch. The material treated came from mine dumps and from the wash in the gulch that contains ferberite float.

A Cle-trac dozer and a TD-9 loader were used to load the trucks, which dumped their loads into a 10-ton hopper at the plant. From the hopper, the ore was fed into a 1-inch trommel. The oversize passed to a 14-inch by 12-foot picking belt, from which the reject was hauled away by truck. The undersize from the trommel passed through a 3- by 60-foot sluicebox. The material caught in the sluicebox was treated in a two-compartment Harz jig. In 1955, this plant saved 306.58 units of tungsten trioxide.

Webb Plant

The Webb plant was below the Ophir mine in Gordon Gulch. The ore came from the Ophir opencut.

Equipment consisted of a 6-hp., Briggs-Stratton, gasoline-driven engine, a 6- by 8-inch jaw crusher, a 6 foot by 24-inch, 3/4-inch screen trommel a one-compartment 18- by 30-inch Harz jig, and a 30-inch by 40-foot riffle-type slime table.

An estimated 5,000 tons of ore has been milled since 1948. Very little work was done in 1956.

Sorting Plants

General

Sorting plants, varying in type from a flat place on a dump, where ore can be sorted, to fairly elaborate plants were found at most operating mines. A ton of waste sorted out meant a saving of about $14 to the shipper. In 1916 Hinmans and Retallack, then the lessees of the Cold Spring mine, had a sorting house in which 11 ore sorters were employed. Two of the present sorting plants are shown in this circular (figs. 17 and 18).

Generally, ferberite ore was easily and quickly detected by an experienced ore sorter.

Cold Spring Sorting Plant

This sorting plant (fig. 17) was built inside the headframe at the new Cold Spring shaft. The ore was dumped from the mine skip into a bin, from which it was fed through a 3- by 12-foot trommel. The undersize dropped into a bin from which it was trucked to the mill. The oversize was washed and passed over a 30-inch picking belt. The coarse low-grade ore was thrown into the bin containing the undersize. The coarse high-grade ore was passed through a jaw crusher to a 24-inch picking belt, on which the ore was sorted by hand

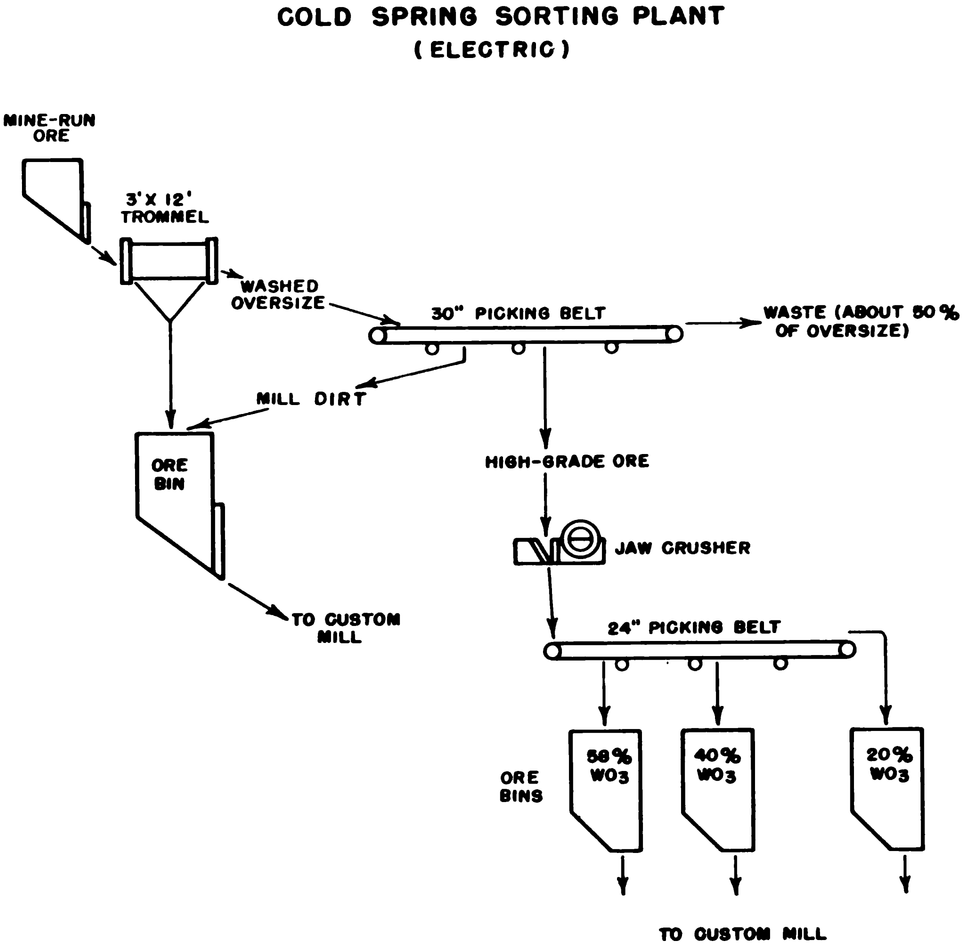


FIGURE 17. - Flowsheet of the Cold Spring Sorting Plant, Boulder County, Colo.

into three grades (about 58, 40, and 20 percent). About 50 percent of the coarse rock fed to the first picking belt was rejected as waste.

Hoosier Sorting Plant

There were two almost identical sorting plants at the Hoosier mine; one was used for custom ore, and the other for Hoosier mine ore (fig. 18). Each plant had a receiving bin, a conveyor, a 1-inch-screen trommel, a picking belt, and a bin for the sorted ore. Custom shippers, such as the operators of the Long Shot No. 3 mine, could sort their own ore before milling.

CONCLUSIONS

Sorting was done in nearly all the mines of the district. In many of the mines ore and waste were shot separately; hence, the cost of mining was higher, but the grade of the product was higher also.

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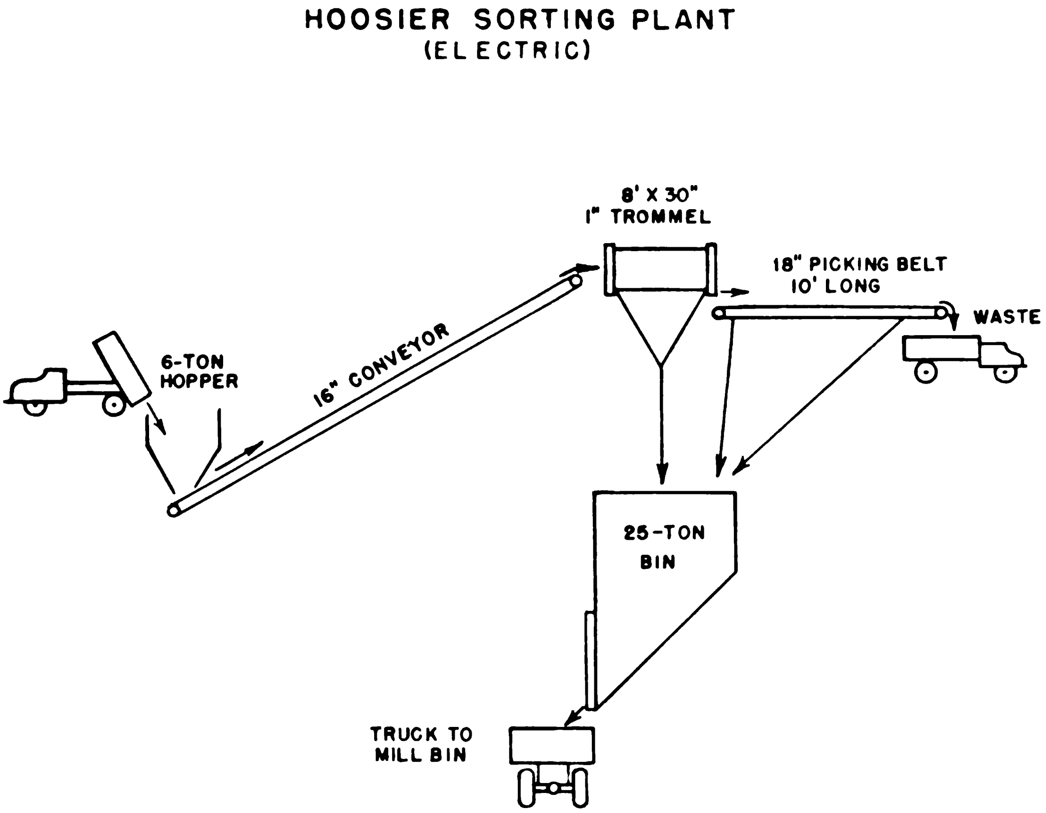

THE HOOSIER MINE HAS TWO ALMOST IDENTICAL SORTING PLANTS ABOUT 200 FEET APART

FIGURE 18. - Flowsheet of the Hoosier Sorting Plant, Boulder County, Colo.

Dumps and float beds could be worked at a profit with a bull-jig plant, when the total cost of screening, sorting, loading, trucking, and jigging was less than $2 a ton and the recoverable tungsten was about 0.2 unit tungsten trioxide per ton.

APPENDIX 1. - Estimated tungsten production by years in Boulder County, Colo.

Year	Units[1]	Average price per short-ton unit of WO_3, dollars	Remarks
1900	2,760	1.25	)
1901	4,200	2.58	)
1902	11,540	3.08	) Number of units uncertain.
1903	13,800	2.49	)
1904	22,800	4.12	) Wolf Tongue mill operating.
1905	36,400	5.57	)
1906	43,500	6.26	)
1907	68,760	9.04	First tungsten boom.
1908	35,040	5.71	
1909	59,580	6.32	
1910	73,260	7.68	Lakewood mill finished.
1911	43,800	5.97	
1912	48,720	6.27	Atolia mine in California became leading individual producer in the world.
1913	57,180	7.24	Primos and Wolf Tongue properties are leading producers in Boulder County.
1914	28,020	7.32	Atolia mine in California out-produced Boulder County.
1915	57,780	29.30	Miners' wages increased to 45 cents per hour.
1916	144,060	33.98	Colorado, leading producer in United States.
1917	162,420	18.40	California, leading producer in United States.
1918	114,600	23.24	Imports of tungsten start from China.
1919	7,800	18.02	Vasco mine, leading producer in Boulder County.
1920	12,960	7.86	Vasco and Wolf Tongue, principal producers in Boulder County.
1921	None	-	No tungsten produced in United States.
1922	None	-	Wolf Tongue Co. kept water out of Cold Spring mine.
1923	14,460	10.00	Wolf Tongue mines.
1924	1,500	8.47	Wolf Tongue, only company mining in Boulder County.
1925	12,060	10.57	
1926	13,920	11.10	
1927	19,920	10.37	
1928	13,740	10.40	
1929	9,120	13.13	
1930	2,820	12.09	New ore shoot found in Cold Spring mine.

See footnotes at end of Appendix I.

APPENDIX 1. - Estimated tungsten production by years in Boulder County, Colo. (Con.)

Year	Units[1]	Average price per short-ton unit of WO_3, dollars	Remarks
1931	5,880	11.02	
1932	([2])	9.20	Wolf Tongue and Cowdery only operators.
1933	5,160	9.58	
1934	20,520	14.57	Mostly from leasing operators of Mammoth Mine.
1935	31,140	13.37	Cold Spring and Mammoth mines.
1936	10,816	14.00 to 16.00	Gold, Silver, and Tungsten, Inc., and Wolf Tongue Co. shipping.
1937	13,144	16.00 to 35.00	Do.
1938	14,418	18.00 to 22.00	Gold, Silver, and Tungsten, Inc., principal shipper, Illinois mine operated 3 months V.C.A. building Conger mill.
1939	28,746	17.11	Good ore discovered in Illinois mine shaft.
1940	43,559	18.00	Miners' wages $4 per day.
1941	38,740	23.41	Includes small quantities from San Juan and Summit Counties.
1942	22,810	24.12	Includes small quantities from San Juan and Summit Counties. Miners' wages 80 cents an hour.
1943	20,522	25.07	Mostly Wolf Tongue and V.C.A.
1944	17,955	23.36	Mostly Wolf Tongue; miners' wages 90 cents per hour.
1945	15,136	23.21	Vanadium Corp. discontinued operating in May.
1946	12,473	20.17	
1947	3,678	25.77	
1948	1,839	26.27	Climax Molybdenum mine in Lake County, Colorado begins production.
1949	96	26.38	United States production off 25 percent.
1950	539	14.00 to 22.00	
1951	3,258	22.00 to 63.00	Defense Minerals Exploration Administration grants loans.
1952	6,683	63.00	Cold Spring mine main producer.
1953	19,143	63.00	Do.
1954	15,797	63.00	Do.
1955	15,935	59.71	Cold Spring Eureka, and Good Friday.
	1,504,407		

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[1] A short ton unit of tungsten trioxide (WO_3) contains 15.863 pounds of tungsten (W).

[2] Production very small.

APPENDIX 2. - Purchase schedule for tungsten ores by Wah Chang Corporation effective, September 14, 1956

(subject to change without notice)

Schedule A

Grade, percent	Price per unit of WO_3	Grade, percent	Price per unit of WO_3	Grade, percent	Price per unit of WO_3
1.....	$17.50	21.....	$30.72	41.....	$33.84
2.....	22.20	22.....	30.88	42.....	34.00
3.....	24.75	23.....	31.03	43.....	35.00
4.....	26.63	24.....	31.19	44.....	36.00
5.....	27.50	25.....	31.34	45.....	37.00
6.....	28.00	26.....	31.50	46.....	38.00
7.....	28.50	27.....	31.66	47.....	39.00
8.....	29.00	28.....	31.81	48.....	40.00
9.....	29.50	29.....	31.97	49.....	41.00
10.....	30.00	30.....	32.12	50.....	42.00
11.....	30.06	31.....	32.28	51.....	43.00
12.....	30.11	32.....	32.44	52.....	44.00
13.....	30.16	33.....	32.59	53.....	45.00
14.....	30.22	32.....	32.75	54.....	46.00
15.....	30.28	35.....	32.90	55.....	47.00
16.....	30.34	36.....	33.06	56.....	48.00
17.....	30.40	37.....	33.22	57.....	49.00
18.....	30.45	38.....	33.37	58.....	50.00
19.....	30.50	39.....	33.53	59.....	51.00
20.....	30.56	40.....	33.68	60.....	52.00

Schedule B (silicate or "horn" ores); schedule B from Hetzer Mines, Inc., schedule.

Same as Schedule A above less $4 per unit.

Notes:

1. The schedule to apply to an ore will be determined by the degree to which the following impurities are removed by simple concentration, and by the extent to which the WO_3 concentrates must be chemically treated, for which a special charge will be made. The classification by our mill superintendent will be final. The following is a list of the undesirable impurities:

    Copper (Cu)
    Phosphorus (P)
    Arsenic (As)
    Sulfur (S)
    Bismuth (Bi)
    Molybdenum (Mo)
    Tin (Sn)
    Zinc (Zn)
    Antimony (Sb)
    Manganese (Mn)
    Lead (Pb)

2. Ore below 1 percent accepted by special arrangement only.
3. Other than ferberite ore accepted by special arrangement only.
4. Ore previously milled accepted by special arrangement only.
5. A sampling charge of $20 will be made on all lots of less than $250 gross value.

APPENDIX 3. - Data on drifts, shafts, and stopes driven in Boulder County tungsten district, 1955-56

DRIFTS

Mine	Size, feet	Type cut	Holes		Explosives per foot, pounds	Drilling, man-hours	Mucking, man-hours	Fuse length, feet	Type of spitter
			Number	Depth, feet					
Cold Spring.......	5 x 7	Burn	18	6	5.5	5	7	8	Hot wire.
Crow No. 13.......	4 x 7	V-cut	12	4	3.0	3	8	5	-
Eureka main heading.........	5 x 8	do.	20	4	7.3	16	16	5	Lead.
Eureka footwall...	5 x 10	do.	20	5	6.2	12	16	5	Do.
Good Friday.......	4 x 7	Burn	16	5	7.0	8	8	6	Thermoignition cord.
Hoosier...........	4 x 7	do.	18	5	6.1	3	8	6	Lead.
Long Shot No. 3...	4 x 7	do.	15	4 1/2	7.5	2	4	5	Hot wire.
Pennsylvania......	5 x 7	do.	17	4	8.3	5	8	6	Lead.
Prospect (crosscut)......	5 x 7	do.	25	5 1/2	10.0	8	8	8	Do.
Sunday............	3 x 7	V-cut	11	3	2.4	1		6	Hot wire.
Tungsten..........	3 1/2 x 7	do.	10	3 1/2	2.4	4	12	5	Do.

SHAFTS

Mine	Size, feet	Cut, type	Holes		Explosives per foot, pounds	Drilling, man-hours	Mucking, man-hours	Method		
			Number	Depth, feet				Timbering	Carrying	Firing
Eureka1/.......	5 x 9	Center cut	20	3	6.3	3	12	3- x 8-inch crib	High low end	Electric caps
Fire Cracker2/.	3 1/2 x 7	do.	16	3	4.2	10	6	Stull and wallplate	do.	5-inch
Good Friday....	4 x 8	do.	24	4	8.7	5	16	do.	do.	Electric caps
Long Shot No. 3	4 x 8	do.	18	4	9.1	3	16	do.	do.	Do.
Pennsylvania...	4 x 8	do.	18	4	8.0	8	16	do.	do.	Do.

1/ Much sorting by hand.

2/ Sunk by lessees.

STOPES

Mine	Type of stope	Remarks	Mine	Type of stope	Remarks
Cold Spring	Shrinkage	2 to 13 feet wide.	Good Friday	Shrinkage	2 to 4 feet wide.
Eureka	Filled	Level fill and spread carpets.	Long Shot No. 3	Open	30 inches wide.

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